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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CVII.—No. 2791.] *LONDON: FRIDAY, JUNE 27, 1919.* [*Registered at the General Post Office as a Newspaper.*] [PRICE 9d. BY INLAND POST ... 11d.

Aveling & Porter, Ltd.,
ROCHESTER, KENT,
and 72, CANNON STREET, LONDON.
STEAM ROLLERS. ROAD LOCOMOTIVES.
STEAM CULTIVATING MACHINERY.
STEAM WAGONS. TRACTORS.
CEMENT-MAKING MACHINERY. 7067

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CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches, BOILER FEED PUMPS.
See Advertisement, page 33, last week.
PATENT WATER-TUBE BOILERS,
AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 3179

John H. Wilson & Co., Ltd.
Birkenhead.
See Illustrated Advertisement Page 18, June 13.

Locomotive Shunting Cranes
Steam and Electric Cranes,
EXCAVATORS, CRANE-NAVVIES, GRABS, CONCRETE-MIXERS,
SHIPS WINDLASSES, WINCHES, and DECK MACHINERY.
6770
LISTS OF STANDARD SIZES ON APPLICATION.
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Ball Bearings
Always British. Large Sizes.
BLACKSTOCK BALL BEARING CO., London Offices: 304, High Holborn, W.C. 1.
For Illustrated Advert., see page 6, April 11. 7356

Petter Oil Engines.
Manufactured by 3591
PETTERS LIMITED, Engineers, Yeovil.
See our illustrated Advt. every alternate week.

Craig & Donald, Ltd., Machine
TOOL MAKERS, JOHNSTONE, near Glasgow.
For class of Machine Tools see our Illustrated Advertisement every alternate week. 1368

Electric Lifts
(UP TO 35 TONS.) 7182
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COVENTRY. 610

Bever, Dorling & Co., Ltd.,
BRADFORD.
HIGH-CLASS ENGINES FOR ALL PURPOSES, also WINDING, HAULING, AIR COMPRESSING and PUMPING ENGINES. 1896

Cranes.—Electric, Steam,
HYDRAULIC and HAND,
of all types and sizes.
GEORGE RUSSELL & CO., LTD., Motherwell, near Glasgow. 7264

Telegrams—"Cylinders," Birmingham.
Weldless-Steel Tubes
for Water-tube Boilers, Superheaters, Blasting, Hydraulic Work, Boring Rods, &c.
TUBES LIMITED, BIRMINGHAM. 8179

Yarrow & Co., Ltd.,
SHIPBUILDERS AND ENGINEERS, GLASGOW.
SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF EXCEPTIONAL SHALLOW DRAUGHT.
Repairs on Pacific Coast
by YARROWS, LIMITED, Victoria, British Columbia. 6676
SHIPBUILDERS, SHIP REPAIRERS AND ENGINEERS.

Campbells & Hunter, Ltd.
SPECIALISTS IN
Drillers & Boring Machinery
for Engine Works and Boiler Shops.
DOLPHIN FOUNDRY, LEEDS. 4547

Yachts, Launches or Barges
Built complete with Steam, Oil or Petrol Motors; or Machinery supplied. Od 3561
VOSPER & CO., LTD., BROAD STREET, PORTSMOUTH.

Cochran MULTITUBULAR AND CROSS-TUBE TYPES.
Boilers.
See page 17, June 20. 1363

Electric Cranes.
7183
S. H. HEYWOOD & CO., LTD., REDDISH.

FOR
Drop Forgings
write
GARTSHERRIE ENGINEERING & FORGE CO., 80, Wellington Street, Glasgow. 6961

Tank Locomotives
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO., LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 7200

The Glasgow Railway Engineering Company,
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MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
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FROM 50 TO 600 YARDS PER HOUR.
D. Whitaker, 6263
1, UNION STREET, LEICESTER.

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See displayed advertisement every alternate week.
JOHN M. HENDERSON & CO., ABERDEEN.

"Spencer-Hopwood" Patent
Sole Makers:
Boilers.
W. H. SPENCER & CO., HITCHIN, HERTS.
See page 15, June 20. 7454

Henry Wells Oil Co.,
11, HAYMARKET,
London, S.W. 1.
"Aptol" Lubricants.
WORKS: SALFORD, MANCHESTER. 7194

Iron and Steel
Tubes and Fittings.
6930
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 103.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, } Bow's Patents.
CONDENSERS, AIR HEATERS,
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 3720

Tubes and Fittings,
IRON AND STEEL.
Stewarts and Lloyd's, Ltd.,
41, OSWALD ST., GLASGOW.
BROAD STREET CHAMBERS, BIRMINGHAM; and LONDON OFFICE—
WINCHESTER HOUSE, OLD BROAD STREET, E.C.
LONDON WAREHOUSE—167, UPR THAMES ST., E.C.
LIVERPOOL WAREHOUSE—63, PARADISE ST.
MANCHESTER WAREHOUSE—34, DEANSGATE.
CARDIFF WAREHOUSE—122, BUTE ST.
BIRMINGHAM WAREHOUSES—NILE STREET, SHEEPSCOTE STREET, and 10, COLESHILL STREET.
See Advertisement page 28. 7268

Die Finished Castings ensure rapid production and reduce prime cost by eliminating machining operations. Write for illustrations to AERATORS LTD., Edmonton, London, N. 18.

"Petrolex" Fire Extincteur
puts out flaming motor spirit, burning oil, electric arcs and every kind of fire.—BRITISH FIRE APPLIANCES Co., Ltd., 109, Victoria St., London, S.W. 1.

R. Heber, Radford, Son & Squire,
ENGINEERING, IRON AND STEEL WORKS
Valuers.
CONSULTING ENGINEERS, REFEREES, AND ARBITRATORS.
Established over 50 years. 7108
15, ST. JAMES ROW, SHEFFIELD.
Telegrams: "Radford, Sheffield." Telephone: 425.

Locomotive Traversers
(ELECTRIC). 7182
S. H. HEYWOOD & CO., LTD., REDDISH.

GOLD MEDAL-INVENTIONS EXHIBITION-AWARDED.
Duckham's Patent Suspended
WEIGHING MACHINES.—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD. LONDON, E.—Hydraulic Cranes, Grain Elevators, &c.
See Illus. Advt. last week, page 15. 7046

Patent
See's Hydro-Pneumatic Ash Ejector.
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4836

Separators
FOR—
EXHAUST STEAM TURBINES COMPRESSED AIR, &c.
STEAM DRYERS,
METALLIC PACKINGS.
Princeps & Co., 6080
SHEFFIELD.

Delivery from Stock:—
NEW 8½-IN. CENTRE HIGH-SPEED LATHES,
BECKER BRAINARD VERTICAL MILLER.
No. 2 KEMPSMITH UNIVERSAL MILLER.
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Belting
GUTTA PERCHA & RUBBER, LIMITED
Toronto - - Canada. 7535

CHANTIERS & ATELIERS
Augustin-Normand
67, rue de Perrey—LE HAVRE (France).
3260
Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

Yarrow Patent
Water-Tube Boilers.
6094
MESSRS. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

John Bellamy Limited,
MILLWALL, LONDON, E.
GENERAL CONSTRUCTIONAL ENGINEERS, 1316
Boilers, Tanks & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.
RAILWAY AND TRAMWAY ROLLING STOCK.
Hurst, Nelson & Co., Ltd.
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3393

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 83, June 6. 2402

Gas and Oil Engine Repairs.
—E. J. DAVIS & CO., Great Eastern Road, Stratford, E. 15.
Tel.: 736 and 737 Stratford.
Gram.: Rapidising, London. 1796

Wanted,
FOR MUNITIONS OF VICTORY,
SCRAP IRON, STEEL AND OTHER METALS
ALL CLASSES OF OBSOLETE PLANT.
WORKS, &c., for DISMANTLING.
JOHN JACKSON & CO., LTD., 7130
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THOMAS SUMMERSON & SONS, LTD.,
DARLINGTON. 6974

Electric Transporters.
S. H. HEYWOOD & CO., LTD., 7183
REDDISH.

P. & W. MacLellan, Limited,
CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF
RAILWAY CARRIAGES AND WAGONS
OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
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Registered Offices: 108A, Cannon St., London, E.C.

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ADVISORY ENGINEER. 7364
AMERICAN PULVERIZED COAL SYSTEMS.
Furnace Design (Melting and Heat Treatment).
Practical Pyrometry. CO_2 Recorders.
COMBUSTION AND FUEL ECONOMY.
Offices: 25, Victoria Street, London, S.W. 1.
Tele. Address: "FUELECON." 'Phone, London."

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND. 7002
See half-page Advertisement page 107, June 13.

B. & S. Massey, Ltd., MANCHESTER.
Steam Hammers,
Power Hammers,
Drop Stamps,
Band Saws. 7226
QUICK DELIVERY. LARGE STOCK.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by SIR WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 7479

ALTERATION TO NAME.

The Name of Richard

MORELAND & SON, LTD., has been changed to :—
MORELAND, HAYNE & CO., LIMITED.
MR. RICHARD MORELAND, Junr. and MR. W. CROSIER HAYNE, Managing Directors, will continue to control the Business.
MR. HAROLD MORELAND is no longer connected with the Company.
80, Goswell Road, London, E.C. 1.
23rd June, 1919. W 763

PRELIMINARY NOTICE.

Institute of Industrial

ADMINISTRATION. — Messrs. BRINDLEY AND ELBOURNE have pleasure in announcing that they are initiating the above as an urgency measure to meet the immediate needs of reconstruction within the factory.
The immediate object is to provide a centre for manufacturing firms desirous of affording to their Managers, Foremen, Technical and Clerical Staff an opportunity to enlarge their knowledge of Industrial administration, covering in that term :—
Technical Organisation,
Production Efficiency,
Labour Administration,
Factory Records,
Factory Costing.
The main programme is to establish correspondence and consultations on a confidential basis, adapted to each individual's experience and requirements.
Lectures and Conferences will be arranged in London and provincial centres to meet the needs of members.
An Advisory Council is contemplated for research work.
Mr. EDWARD T. ELBOURNE, author of "Factory Administration and Accounts," will act as Organising Secretary.
Further particulars on application by post to—
Messrs. BRINDLEY & ELBOURNE,
Consulting Engineers,
110, Victoria Street,
Westminster, S.W. 1.
W 842

NATIONAL FOREMEN'S ASSOCIATION.
ENGINEERING AND ALLIED TRADES.
Registered under the Trade Union Act.

The Second Annual Delegate

MEETING of above will be held in the Middlesex Rooms at the Great Eastern Hotel, Liverpool Street Station, on SATURDAY and SUNDAY, JULY 12TH and 13TH, commencing Saturday at 3.30 p.m.—All communications should be addressed to H. W. REID, General Secretary, 81, High Holborn, W.C. 1. W 706

Inst. C.E., I. Mech. E., B.Sc.,

and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—39, Victoria St., Westminster, S.W. 7470

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Tuition. Also Postal Courses in Mechanical Engineering, Aircraft Design and Mathematics.—PENNINGTONS, 254, Oxford Road, Manchester.

I.C.E. Correspondence

COACHING. 15 years' continuous success. New papers "Engineering Drawings, Specns. and Quantities" now ready.—7434, Offices of ENGINEERING.

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Courses for B.Sc., Inst.C.E., Inst Mech.E., and all Technical Examinations conducted by Honours (Engineering) University Graduate and fully qualified Engineer. Fees moderate.—Address, 7676, Offices of ENGINEERING.

Personal Tuition for

A.M.I.C.E., &c., EXAMINATIONS by professional man. No failures 1903 to 1914. Now resuming work in London; terms.—Address, W 472, Offices of ENGINEERING.

TENDERS.

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

For Sale, by Public Tender,

GRAIN HANDLING APPARATUS, AT NEWPORT, MON., comprising the following :—
Four Hopper Weighing Trucks, each complete Hopper and Two Weighing Machines housing, doors on one side.
12 30 ft. Horizontal Portable Conveyors, 22 in. belt.
12 Delivery Hoppers, for use with conveyors (bulk).
12 Receiving Hoppers, for use with conveyors (bulk).
Four Sharp Corner Hoppers, for use with conveyors (bags).
Four Bulk Pilers (Portable).
Four Bag Pilers (Portable).
One Excavator.
One Automatic Weigher (Portable).
Four 1-ton Priestman Grabs.
Sets of Spares for the whole of the above plant.
The Plant will be on view from July 1st to 14th, 1919, and Tenders will be received by the Office of Works up to the 31st July.
For further particulars, application should be made to the CHIEF ENGINEER, ENGINEERING DIVISION, H.M. OFFICE OF WORKS. W 816

ALFRETON URBAN DISTRICT COUNCIL.

TO MAKERS OF BORE-HOLE PUMPS.

The above Council is prepared to receive

Tenders for Supplying and

FIXING at Blakelow, in the parish of Ashover, Derbyshire, a BORE-HOLE PUMP of 10 in. diameter.
Particulars may be obtained of the undersigned.
Sealed Tenders, endorsed "Bore-hole Pump," accompanied by specifications and prints, to be delivered at my office not later than Monday, July 7th, 1919.
The Lowest or any Tender not necessarily accepted.
R. F. WARD,
Council Offices, Water Engineer.
Alfreton. W 580

COUNTY COUNCIL OF MIDDLESEX.

TO CONTRACTORS.

GREAT WEST ROAD.

CONTRACT No. 1.

The County Council of Middlesex invite

Tenders for the Work and

MATERIALS REQUIRED in the Construction of the First Section (a length of about three miles) of the proposed new Great West Road, and a new spur road and widening, about 700 yards long, with other contingent works of bridge construction, &c.
The Great West Road, will be 80 feet wide, between fences (with cuttings and embankments), and included in the Contract there will be :—
(a) About 13 miles of soil and surface water sewers;
(b) „ 330 cylindrical manholes; and
(c) „ 11 subways for gas and water mains.
The Plans, Sections, Specification of Works, and Conditions of Contract, prepared by me, may be seen, and Bills of Quantities obtained, at my Offices by intending Contractors (on payment of Twenty Guineas, which will be returned on receipt of a bonâ-fide Tender), on, and after, July 10th, 1919.
Tenders, endorsed "Great West Road—Contract No. 1," to be delivered, in sealed envelopes, to the Clerk of the County Council, Middlesex Guildhall, Westminster, S.W. 1, not later than Twelve o'clock on MONDAY, JULY 28TH, 1919.
The lowest or any Tender will not necessarily be accepted.
H. T. WAKELAM,
Middlesex Guildhall, M.Inst.C.E.,
Westminster, S.W. 1, County Engineer.
12th June, 1919. W 578

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

TRADESMEN'S TOOLS, &c., FOR SALE BY TENDER.

The Undermentioned Material

IS FOR DISPOSAL :—
AT WOOLWICH ARSENAL.
Ref. D.D. S./Group/76.
Tradesmens' Tools as follows :—
Anvils; 5 lb. 10 ox. Awls, various; Bellows, various; Braces, carpenter's; Bits, nose; Chasers, fine thread, various; Chisels; Creasers; Crew Bars; Cutters; Fullers; Gimlets; Gauges; Grindstones; Hammers, rivetting, &c.; Tinman's Block; Solders; Horses, tinmen's; Irons, various; Knives, various; Lead, punching, pieces; Mallets; Needles, various, Palms, saddler's; Pincers, various; Pipe Cutters; various sizes; Planes, various; Platers, angle, &c.; Pliers; Pots, glue; Pritchels, farrier's; Punches, oval, various sizes; Rasps, various; Rippers, slater's; Rules, glazier's, &c.; Saws, various; Slices, farrier's, Snaps, tinman's, &c.; Spanners, various; Stakes, smith's; Stamps, farrier's; Sticks, bossing, &c.; Stones, farrier's; Tongs, farrier's, &c.; Tools, blacksmith's; Vices.
Hatchets, 20,000 with D.D./8/Group/94.
Sheathes, 20,000 „
Lanyards, 20,000 „
Bolts with Nuts (large quantities, various sizes) D.D.8./Group/118.
Csk. Hd. Sqr.; Csk. Hd. Sqr. Bevelled; Csk. Hd. V.; Hex. Hd.; Csk. Hd. Sqr.; Bosshead Square; Square Head; Bosshead, bright slotted; Cheesehead, square; Cheeseheads, 1 in., 1¼ in.; ¾ in. dia. Bosshead V. Nuts, Hex. Castellated; Nails, steel clasp, 2 in.; Nails, steel clout flathead 1¼ in. and 1½ in.; Nails, steel clout bosshead, ¾ and 1¼ in.; Nails, iron mop; Tacks, steel clout, ¾ in., 1¼ in. and 1½ in.; Staples, special.
Hammers, stonebreaking, 2 lb., 4 lb. and 6 lb. D.D.8./Group/172.
Pickaxe Handles, 36 in., 84,000. D.D.8./Group/222.

AT DIDCOT.

Wire Nails, large quantities D.D.8./Group/117.
„ „ rd. 1½ in. and 3 in. „
„ iron spike, 5 in., 6 in., 7 in., 8 in. and 9 in. „
„ steel cut nosehead 7 in. „
Staples, fencing (No. 8 B.W.G.), 1½ in. splice cut ... „
„ fencing (No. 8 B.W.G.), 1½ in. pointed ... ... „
Hammers, stonebreaking, 4 lb., 10,000 ... ... D.D.8./Group/163.
Pickheads, 8 lb., 16,000 ... ... D.D.8./Group/244.
Shovels, square mouthed, 12 in. by 10 in., 15,000 ... ... „
Wheelbarrows, entrenching, without wheels, 9750 ... ... „
Wheels, flat tyre, 17,750 ... ... „

AT BURTON-ON-TRENT.

Brass Wire Nails, 2 in. by 10 G., 33,000 lb. ... ... D.D.8./Group/185.
Brass Wire Nails, 1 in. by 14 G., 4500 lb. ... ... „
Brass Wood Screws, 1¼ in. by 12 G., 21,000 gross ... ... „

AT CHILWELL, NOTTINGHAM.

Pick Helves, sah, 36 in., 100,000 D.D.8./Group/239.

Samples may be seen at D.D. 8.s, Engineers' Store (Gallery), Agricultural Hall.
Further particulars and Tender Forms may be had on application to the CONTROLLER, FACTORY CONSUMABLE STORES SECTION, GOVERNMENT DISPOSAL BOARD, 37-41, Old Queen Street, Westminster, S.W. 1.
Please quote references. W 740

G. R.

The Admiralty has for Dis-

POSAL the following DIESEL ENGINES ex German Submarines, considered suitable for commercial utilization :—
Four Cycle Non-reversible, B.HP. 140 each, 450 Revolutions per minute. Two now in London.
Four Cycle Reversible M.A.N. Designs, B.HP. 1200 each, 450 Revolutions per minute. Two now at Swansea.
Tender Forms may be obtained on application to the DIRECTOR OF CONTRACTS (Sales Branch), Admiralty, S.W. 1, and the engines may be inspected on presentation of Tender Form. W 697

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

For Sale, by Public Tender,

GASHOLDERS, TANKS, &c.
Large Water Tank, 56 ft. long, 32 ft. broad, 8 in. high. Capacity 400 tons. Built up of 4 ft. square sections with lead strips between plates.
Steam Pipes, C.I. Suction Pipes, rose and retaining valves, steel spigot and socket pipes. Hydrant and Sluice Valves. Above lying at Olna Whaling Station, Stromness.
One Gasholder, Two Spiral Lift Tanks, 43 ft. diam., 12 in. inlet and outlet pipes, capacity 40,000 cubic feet.
The above Gasholder is lying in sections ready for erection.
Tenders must be submitted by Wednesday, July 9th. Full particulars and Tender forms, together with permits to view, to be obtained from the CONTROLLER, Machinery and Plant (Demobilisation), Charing Cross Embankment Buildings, London, W.C. 2. W 706

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

SALE BY PUBLIC TENDER.

THE "EDITH CAVELL" PROJECTILE FACTORY
(Messrs MECHANS, Ltd.) Overnewton, Glasgow.

Tenders are Invited for the

purchase of Machine Tools, Plant, Office and Canteen Furniture at the "Edith Cavell" Projectile Factory, Glasgow, comprising :—
Heavy Duty Lathes. 9½ in. centres.—By J. F. Low.
Sensitive Drilling Machines.—By Jones & Shipman
Double-Sided Single-Stroke Power Presses—By Bradley & Craven.
Scales and Weighing Machines—By Pooley.
Air Compressor Plant—By Lacey Hubert.
Vertical Patent Multibular Boiler, 7 ft. diam. by 15 ft.—By Cochran.
A.C. Motor 30 HP. 3 phase, 440 volts, 25 periods, 750 r.m.p.—By Brush & Co.
A.C.G. Motor, 50 H.P., 3 phase, 440 volts, 25 periods, 750 r.m.p.—By E. Brook, Ltd.
Quasi Arc Electric Welding Units for 110 volts, single phase, 25 periods.
Narrow pattern Forge Blowers—By Keith and Blackman.
Gas Welding Plant including Acetylene Generator, Purifiers, etc.
Shafting, Pulleys, Belting, etc.
Time Recorder Model 950—By International Time Recorder, Ltd.
Office and Canteen Furniture and Equipment.
Purchasers to dismantle and remove in all cases.
Tenders for the above will be received up to Ten a.m., on July 9th, 1919.
Tender Forms and Permits to view can be obtained from the CONTROLLER, Plant and Machinery Section, Charing Cross Embankment Buildings, W.C. W 730

CITY OF BRADFORD.

SEWAGE DISPOSAL WORKS.

STEAM DRIVEN AIR COMPRESSOR
(Contract No. 27).

The Corporation are prepared to receive

Tenders for the Supply,

DELIVERY and ERECTION of ONE STEAM-DRIVEN AIR COMPRESSOR; capacity 1000 cubic ft., 100 lb. pressure.
Further particulars may be obtained at the Office of Mr. JOSEPH GARFIELD, M.Inst.M.E., Beholt Hall, Shipley (Station, Apperley Bridge, Mid. Rly.).
Tenders, endorsed "Sewage Disposal Works—Contract No. 27," must be delivered at the Office of the undersigned, not later than Twelve o'clock noon, on MONDAY, 7th JULY, 1919.
The Coporation do not bind themselves to accept the lowest or any Tender.
FREDERICK STEVENS,
Town Hall, Town Clerk.
Bradford,
June, 1919. W 633

CITY OF BRADFORD.

SEWAGE DISPOSAL WORKS.

SEWAGE EJECTORS (CONTRACT No. 26).

The Corporation are prepared to receive

Tenders for the Supply, De-

LIVERY, and ERECTION of THREE EJECTOR CYLINDERS, 1,400 galls. total capacity; with air receiver, air mains, and all necessary pipes, valves, &c., complete.
Further particulars and copies of Specification may be obtained at the Office of Mr. JOSEPH GARFIELD, M.Inst.C.E., Beholt Hall, Shipley (Station, Apperley Bridge, Mid, Rly.).
Tenders endorsed "Sewage Disposal Works, Contract No. 26), must be delivered at the Office of the undersigned, not later than Twelve o'clock noon, on MONDAY, 7TH JULY, 1919.
The Corporation do not bind themselves to accept the lowest or any Tender.
FREDERICK STEVENS,
Town Hall, Bradford, Town Clerk.
June, 1919. W 632

The Guardians of the Bradford

POOR LAW UNION have FOR DISPOSAL a BARNARD WATER COOLING TOWER, with Tank, a Volz combined Surface Condenser and Feed Water Heater; approx. capacity 5000 lb. of steam per hour. Detailed particulars, authority to view, and Form of Tender may be obtained from FRED HOLLAND, Engineer and Architect, 22, Manor Row, Bradford. The highest or any Tender not necessarily accepted.
By Order,
GEORGE M. CROWTHER,
Union Offices, Clerk to the Guardians.
22, Manor Row, Bradford. W 755

TENDERS.

THE COMMISSIONERS OF HIS MAJESTY'S WORKS, &c., are prepared to receive

Tenders, before Eleven a.m.

on Monday, the 7th July, 1919, addressed to the SECRETARY, H.M. Office of Works, &c., Storey's Gate, Westminster, London, S.W. 1, for the Supply of STEAM TUBES and FITTINGS during a period of six or twelve months from date of acceptance of Tender.
Forms of Tender, &c., may be obtained on application to the CONTROLLER OF SUPPLIES, H.M. Office of Works, &c., King Charles Street, Westminster, London, S.W. 1. W 805

URBAN DISTRICT COUNCIL OF FELIXSTOWE AND WALTON.

Tenders are Invited for the

PURCHASE of the following, which can be viewed, by appointment, at Felixstowe :—
Two O.B. size Horizontal Stockport GAS ENGINES, piston 12 in. dia., 18 in. stroke, each fitted with two extra heavy fly-wheels, sensitive governor, electric and tube ignition, speed 210 r.p.m.
Two 4-pole shunt-wound GENERATORS, 20 Kw. each, speed about 900 r.p.m., 200-220 volts with slide rails.
Tenders should be addressed to the CLERK to the Urban District Council, at the Town Hall, Felixstowe. The machines will be dismantled by the staff of the Generating Station, and delivery will be given on the generating station site.
The Council do not bind themselves to accept the highest or any Tender. W 691

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely :—

	Fee for Specification.
STEEL FISHPLATES ...	10/-
STEEL FISHBOLTS, &c. ...	10/-
TIE BARS, GIBS & COTTERS	£1

Specifications and Forms of Tender may be obtained at this Office on payment of the fee for the Specification, which payment will not be returned.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Steel Fishplates," or as the case may be, not later than Eleven o'clock a.m., on TUESDAY, the 8TH JULY, 1919.
The Directors do not bind themselves to accept the lowest or any Tender.
Company's Offices, R. H. WALPOLE,
48, Copthall Avenue, Secretary.
London, E.C. W 758

COUNTY BOROUGH OF GRIMSBY.

ELECTRICITY DEPARTMENT.

The Corporation are prepared to receive

Tenders for the following :—

Specification No. 135.
SECTION 1. WATER SOFTENING PLANT.
„ 2. FEED TANK.
„ 3. BOILER FEED PUMP (electrically driven).
„ 4. BOILER FEED PUMP (steam driven).
Any Section may be Tendered for separately.
Specifications and Drawings may be obtained from the undersigned on payment of a deposit of one guinea, which will be returned on receipt of a bona-fide Tender.
Tenders are to be received by first post Wednesday, July 14th, 1919.
W. A. VIGNOLES, Lt.-Col.,
Borough Electrical Engineer.
Corporation Electricity Works, Grimsby.
June, 1919. W 738

BRAINTREE, ESSEX.

By Order of THE CRITTALL MANUFACTURING CO., LTD., who are reorganising their works for Peace production.—Messrs.

Fuller, Horsey, Sons and

CASSELL will SELL by TENDER, in LOTS, SURPLUS MACHINERY AND TOOLS, including :
A Marshall Compound Cornish Boiler, with Binnie Stoker, Feed-water Heater, and Pump.
Two 60 KW., 110 volt Steam Electric Generating Sets, with Marshall Horizontal Compound Engines.
A Compton 200 KW., 466 volt D.C. Generator.
Two 78 KW. Compton Belt-driven Generators (460 and 110 volts).
Patent Suction Gas Plant, by the Power Gas Corporation. Capacity 14,000 cubic feet per hour.
Seven Heavy Type Power Friction Fly Presses.
Three Boiler Tanks, 3800-6000 and 7000 gallons.
40 Oil-fired Crucible Furnaces, for 200 lb. Crucibles.
14 Keith-Blackman No. 1 High-pressure Fans.
A Special 150 lb. Crucible Furnace, by the Davis Furnace Co.
Three Regenerative Oven Furnaces.
Two Fletcher-Russell Oven Furnaces.
Set Hydraulic Pressure Pumps.
Hydraulic Riveter, by Berry & Co.
38 Teak finished Fire-Resisting Doors.
10 tons High-Speed Steel.
A RENFIRLT ELECTRIC FURNACE, 30 cwt. capacity, with three 125 KW. Phœnix Alternators, Switchgear, and License to use same.
The Vendors will load all Lots on Rail Free of Charge.
Tenders must be delivered at the Auctioneers' Offices, 11, Billiter Square, E.C. 3, not later than Four p.m. on TUESDAY, JULY 15th.
Catalogues and Forms of Tender to be obtained of Messrs. FULLER, HORSEY & CO., Mechanical Auctioneers and Valuers, 11, Billiter Square, E.C. 3. (Avenue 3089.) W 767

BRITISH CONCRETE SHIPBUILDING: UNIT SYSTEM CONSTRUCTION.

By W. NOBLE TWELVETREES, M.I.Mech.E., M.Soc.Ing.Civ.

IN most of the British yards established for the building of reinforced concrete ships and barges, the monolithic system of construction is predominant, the idea being to follow closely the methods successfully applied in the forms of buildings, reservoirs, bunkers and other land structures. In some cases pre-cast parts or units, such as transverse frames or hull plates, have been incorporated with monolithic work, a method of procedure which is often convenient in land structures, as for instance, railway or highway bridges which have to be built or rebuilt in a minimum period of time with the object of interfering as little as possible with traffic. The method has also proved useful in the case of wharves and jetties in tidal waters, as a means of overcoming the difficulty of executing concrete work between high and low-water levels, or even below the latter.

Two or three shipbuilding firms have gone a step further by adopting pre-cast units on a more extensive scale. Thus, in the Waller system, described in a previous article, the skin of the hull is formed entirely of pre-cast units erected and combined with monolithic transverse frames and longitudinal members. In the Stroyer system adopted at Tilbury, pre-cast units of very large dimensions are employed in forming the parallel portion of the hull, the transverse frames and curved ends being moulded in the usual manner. A third method to which the present article is devoted consists in the use of pre-cast units of relatively small size for the construction of the entire hull, the units being carefully jointed together after erection and braced by the addition of stringers, keelsons and other members moulded *in situ*.

The system now in question is that originated by Mr. Harry C. Ritchie, A.M.Inst.C.E., A.M.I.N.A., of Liverpool, and adopted so far by Concrete Seacraft, Limited, Fiddlers Ferry, Lancashire; Messrs. Hughes and Stirling, Preston Dock; Stuart's Concrete Ship Company, Limited, Northfleet; and Blackett's Concrete Ships, Limited, Stockton-on-Tees. The writer is informed that arrangements are now in progress for the employment of the system in Italy, Scandinavia and India.

In the development of his unit system, Mr. Ritchie had in view two important ends: (1) To reduce to an absolute minimum the amount of timber supports and shuttering required on the building berth; and (2) the arrangement and spacing of frame members in a manner similar to that generally specified for steel ships, and a reduction in scantlings with consequent reduction of structural weight.

To assist in making clear the essential features of the system, a diagram, Fig. 1, is annexed, showing the units adopted by Mr. Ritchie and the means adopted for jointing and bracing them after erection. The hull is built up of units, each consisting of a thin plate and two deep flanges. Therefore the complete unit has a troughlike cross-section, but the depth of the flanges is varied suitably with the position of the units in the hull of the vessel Referring to Fig. 1, the two rows of units for the bottom have flanges of uniform depth which may be left solid or pierced by oval openings as in the diagram. Rectangular openings are formed in the flanges just above the upper surface of the plate to provide for the passage of diagonal bars which are afterwards concreted so as to constitute bracing members.

When the bottom units have been placed in position, the abutting flanges are cemented together so that each jointed pair of flanges forms part of a transverse frame. The units for the sides of the hull are similarly formed and jointed together. Each bottom unit extends from the bilge to the middle line athwartship, so that two units make up the full span of the bottom. The side units extend from the bilge to the sheer strake, and above them are the deck beam units of rectangular section, not comprising any portion of the deck slab, which is moulded *in situ*. All the longitudinal members are moulded *in situ* about the units after the latter have been assembled. In positions where the longitudinals are required to connect the ends of units, as at the centre line and bilges, the main reinforcement of the units projects in hooked form, the loops from adjacent units being concentric so that they can be connected securely by means of steel pins and wedges. The other longitudinal members are formed by passing the main reinforcing bars through the openings left in the bottom and side units, and by concreting in moulds after the auxiliary reinforcement has been assembled.

An important feature of the Ritchie system is the provision of diagonal bracing as shown in the diagram. The reinforcing bars for the diagonals are close to the inner surface of the shell plates and pass through the openings left for the purpose in the flanges of the units. The bars are anchored to the shell by means of U-shaped stirrups, the ends of which project from the pre-cast units along predetermined lines. The diagonals are completed by concrete moulded *in situ*.

One of the advantages of constructing ships of relatively small pre-cast units is to be found in the fact that the units can be made with the shell face upwards. Thus, what is destined to form the outer surface of the hull can be trowelled perfectly smooth, thereby reducing skin friction to a minimum, and at the same time providing a good and pleasing exterior surface. The operation of casting units is illustrated by Figs. 2 and 3, Plate LXIV. In one case the reinforcement is shown assembled in readiness for the erection of the shuttering, and in the other case a number of the completed units are to be seen after removal of the shuttering. The manner in which the pre-cast units are applied on the building berths is illustrated in Figs. 4 and 5 on the same plate. These views were taken at the yard of Concrete Seacraft, Limited, on the River Mersey.

The vessels built at the yard in question, and at the other yards where the Ritchie system has been adopted, are with one exception dumb barges of 1,000 tons deadweight capacity in general accordance with the specification and drawings of the Ministry of Shipping. Therefore, although the actual details of construction were modified to suit the unit system, the vessels are of practically the same dimensions as those described and illustrated in previous articles, and for this reason it is unnecessary to occupy space by reproductions of general arrangement drawings.

The views given as Figs. 6 and 7, Plate LXV, are, however, of special interest as showing the essential features of the Ritchie system in detail. In Fig. 7, the plan shows, the diagonal reinforcement in the slab, or plate, of a unit for the bottom of the barge, the projecting bars being those which are passed through the rectangular openings in the flanges. The sectional elevation in Fig. 6 shows the main and auxiliary reinforcement in the unit flanges. It will be noticed that each unit has three transverse stiffeners between the flanges, and the hooked ends of the main bars provide for very secure connection with the corresponding bars of the centre and bilge keelsons. In the case of the side keelsons, the reinforcing bars are passed through rectangular holes and recesses formed in the flanges of the units. In Fig. 8, the complete cross-section A A shows the shape of a typical bottom unit. Fig. 10 illustrates the plate reinforcement, and the manner in which the rods are bent around the main bars, while Fig. 9, section C C, makes clear the disposition of the reinforcement at points where the flanges are pierced by openings for the passage of bars as reinforcement for the diagonal bracing members.

Fig. 11 is a midship section of a 1,000-ton barge. This drawing is self-explanatory and shows all essential features of the construction. It will be understood, of course, that the positions and number of the joints are varied at the bow and stern conformably with the lines of the vessel.

Figs. 12 to 17, Plate LXV, give some important details of the connections between keelsons and units for the bottom and sides of the hull. In Fig. 17, parts of a bottom unit are shown together with the lower end of a side unit, the keelsons and the connections between the hooked bars projecting from the units being fully detailed. As previously explained, the centre line and bilge keelsons are continuous and fill the longitudinal gap between successive units,

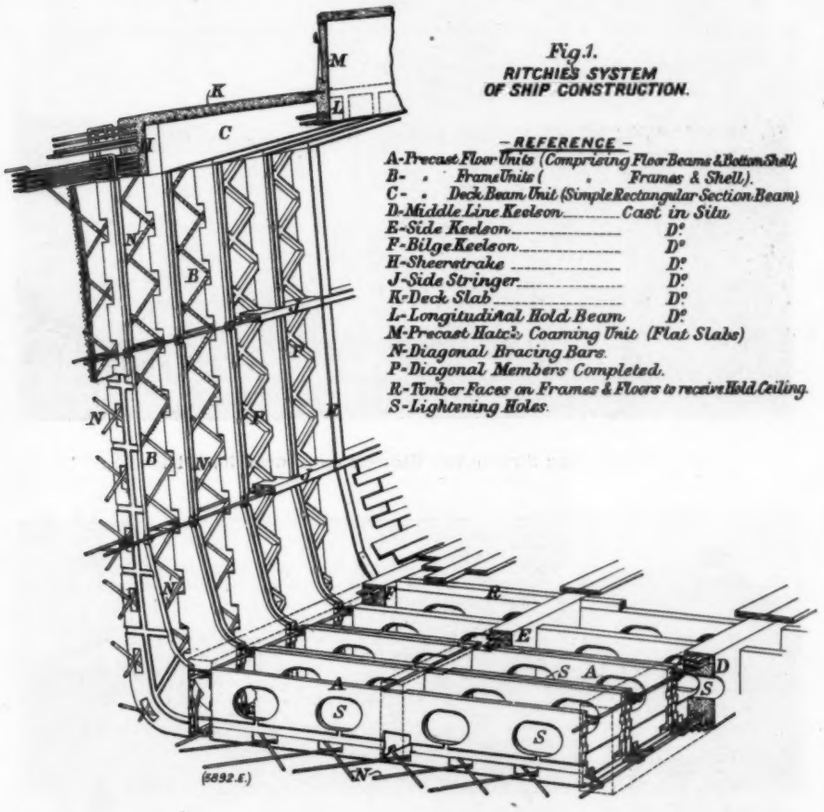

Fig. 1.
RITCHIE'S SYSTEM OF SHIP CONSTRUCTION.

– REFERENCE –

A-Precast Floor Units (Comprising Floor Beams & Bottom Shell).
B- . Frame Units (. Frames & Shell).
C- . Deck Beam Unit (Simple Rectangular Section Beam).
D-Middle Line Keelson ..... Cast in Situ
E-Side Keelson ..... Dº
F-Bilge Keelson ..... Dº
H-Sheerstrake ..... Dº
J-Side Stringer ..... Dº
K-Deck Slab ..... Dº
L-Longitudinal Hold Beam ..... Dº
M-Precast Hatch Coaming Unit (Flat Slabs)
N-Diagonal Bracing Bars.
P-Diagonal Members Completed.
R-Timber Faces on Frames & Floors to receive Hold Ceiling.
S-Lightening Holes.

while the side keelsons are continuous only so far as the top and bottom booms are concerned, the intermediate portion, corresponding with the web of a steel girder, being moulded between the flanges of the units, due care being taken to make the joint between the pre-cast and subsequently added concrete as perfect as possible. Fig. 14, a part plan of centre-line keelson illustrates the connection of the reinforcement projecting from the units, by means of steel pins and wedges. The other details reproduced show the keyed faces of the bottom and side units, and the manner in which the abutting flanges are jointed after having been assembled in place.

The first vessel completed on the Ritchie system was a 250-ton barge built on precisely the same principles as those described and illustrated, but in this case the lines of the vessel are curved throughout exactly as in a steel ship, a feature of some novelty in connection with concrete vessels constructed in moulds or of pre-cast units.

This 250-ton vessel, named the Elmarine, was launched early this year, and it is claimed by the designers that she is the lightest boat of her size which has received Lloyd's classification. The thickness of the sides is only 1¾ in., instead of 3½ in., which is the requirement of Lloyd's Registry for boats constructed on the monolithic principle, and it is stated that tests conducted on the thin slabs show that under a 100-ft. head of water remaining on for four days, the percolation into the concrete is invariably less than ⅛ in.

It may also be mentioned that careful observations made after the launch revealed no sign of structural weakness in any part of the hull, another feature being the perfect watertightness of the vessel.

In its present state, the concrete shipbuilding industry has to overcome various drawbacks. Apart from the natural reluctance of owners to try experiments in the way of vessels built of a new shipbuilding material, the concrete ship still suffers from the handicap of excessive deadweight as compared with a steel ship of equal tonnage capacity. A very considerable proportion of the excess weight will undoubtedly be eliminated as soon as sufficient practical experience has been gained to show designers to what extent existing designs may be modified without incurring unjustifiable risks.

In the case of steel ships, the scantlings have been cut down by as much as 60 per cent. below the original hypothetical standard, and it is only reasonable to infer that a similar process of reduction will take place in the scantlings of concrete vessels. At present, steel shipbuilding has a long start, and in the interests of the concrete branch of the industry, it is very desirable that every system of construction and every type of design should receive impartial consideration.

As our readers are aware, there are three main systems of construction—the monolithic system, the plastered skeleton system, and the pre-cast unit system. A good deal has been urged for and against each of these, and it may be doubted whether absolute agreement will ever be attained among the advocates of the three systems, the probability being that one system may be regarded as the best and most suitable for vessels up to some given size, and that another system may be thought preferable for larger vessels. Whatever may be the outcome of future experience, all systems are, as we have said, deserving of the most careful investigation, and the unit system described in this article is clearly one worthy of study as representing a bold attempt to solve some of the problems presented to the concrete shipbuilder.

The views held on the subject of unit construction in shipping registry circles may be judged by the remarks of Mr. F. Stephen, the chairman of the Technical Committee of the British Corporation, who at the last general meeting of the corporation, said: "For some years before the war the committee had evidence of increasing interest in the subject of concrete ships through designs submitted —chiefly by continental designers. There has been, as a result of the war, an assimilation of technical ideas which gives hope that structural strength is being based on sound foundations. Practical opinion is hardening to the view that the original conception of casting the whole hull in one, is not likely to compete economically with a system in which parts are cast separately and afterwards joined together. If it be shown that satisfactory jointing is easily possible then one might prophesy that the line of development for the industry would be towards methods which resemble the fabrication of steel ships, where as many parts as possible will be cast in one mould, and afterwards assembled."

UNITED STATES NAVAL AIRCRAFT FACTORY, PHILADELPHIA.

THE Transatlantic flight of the American seaplane N.C. 4 focuses attention upon some interesting points of difference between naval aviation in the United States and Great Britain. In the former country the authorities have continued the policy whereby the Secretary of the Navy is responsible for the production of aircraft for naval purposes. The seaplane and flying boat have been developed rather than the aeroplane working from specially-constructed ships; this trend of policy has resulted from a consideration of the purposes for which machines heavier than air were immediately required for the United States Navy, the circumstances under which they would probably act, and the conditions of sea and atmosphere that would generally prevail in the areas over which they would operate.

Another interesting feature has been the inauguration at a naval dockyard of an aircraft factory. The advantages claimed for such an establishment are, that it provides a place where experimental models can be made and developed at short notice, and also that from its working, valuable information becomes available as to the cost of production and experimentation. Moreover, from time to time, minor changes are necessary to improve the military efficiency of aircraft; in developing these modifications a Government-owned plant has its special value, as its officers can fully appreciate the military aspects of the problem, and executive officers are at greater liberty to discuss the matter and advise as the improvements are worked out. When this has been accomplished other manufacturers can be instructed by means of particulars furnished from the Government works.

Influenced by these considerations, when, shortly after the American declaration of war, it became apparent that the aircraft producing capacity of the United States was inadequate, the Secretary of the Navy directed the Chief Constructor to prepare a scheme for a naval aircraft factory. Admiral D. W. Taylor, who is responsible for the production of aircraft for the Navy, proposed to establish such works at the Navy Yard, Philadelphia, conveniently close to Washington, where there was ample land already owned by the Government, where advantageous conditions as to labour, material and transportation could be expected, and where the river area provided sufficient space for test flying. This project was authorised on July 27, 1917. The factory was intended for the construction of simple machines for the instruction of naval aviators, the capacity to be 1,000 machines per year, but in view of the growing importance of aircraft in naval warfare it was decided to erect buildings of a permanent nature which could be used for the construction of military machines.

FIG. 1. THE SITE OF THE FACTORY ON AUGUST 10, 1917.

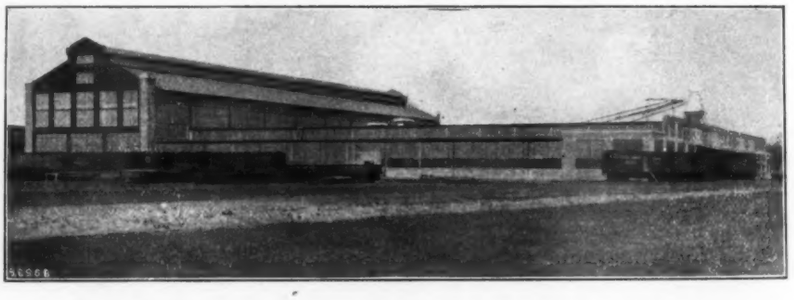

FIG. 2. THE ORIGINAL FACTORY AS COMPLETED ON NOVEMBER 28, 1917.

The contractor was directed to proceed with the work on August 6, 1917, and on August 10 the ground was staked out for the building. Fig. 1 shows the site at this time. On October 9, work was sufficiently advanced for occupation to commence. Seven days later the first machine tool was working, and by November 28, 1917, the factory was completed, as seen in Fig. 2 annexed, and Fig. 5 on Plate LXVI; the latter shows the hull and assembly shop.

In December, 1917, on account of the large increase in the naval aircraft programme and in view of the successful results already indicated from the then existing factory, it was decided to enlarge the works sufficiently to take care of the major portion of the expanded programme. The establishment so enlarged was to be capable of producing 480 flying boats before January 1, 1919, and in order that this output might be maintained it was to become an assembly factory, the manager was

to be responsible for the construction of parts in the neighbourhood, while assembling, testing and packing were to be done at the main works. On February 7, 1918, the additions were authorised, and contracts for the buildings were awarded by the end of that month. A large part of this extension was completed and occupied by the date the armistice was signed, the whole establishment then existing is shown in Fig. 3, which is an interesting picture taken from the air. The general lay-out of hostilities comprised 25 per cent. of the 3,640 workers in the factory. In addition to this number, over 7,000 persons were employed in the various privately-owned factories which were manufacturing parts under the manager's direction for assembly at the main works.

The original scheme to build school planes was changed on account of the great demand for service machines, and the first work done at the factory was to construct flying boats of the H. 16 type.

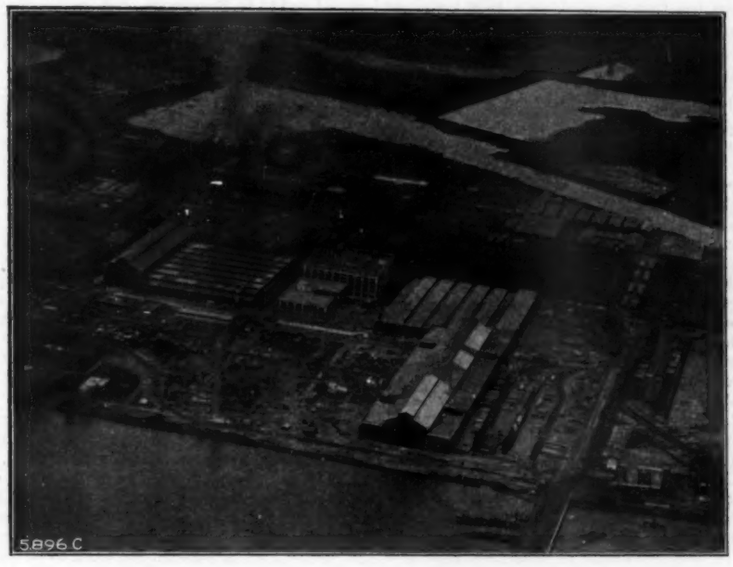

FIG. 3. THE FACTORY AS SEEN FROM THE AIR ON NOVEMBER 11, 1918.

FIG. 4. FLYING BOATS PACKED AND AWAITING SHIPMENT.

is clearly shown, as well as machines afloat ready for testing and others packed for shipment; the original buildings may be seen to the left. Fig. 4 shows how the boats were packed for despatch to Europe, while Figs. 6, 7, and 8, on Plates LXVI and LXVII, give three views of the interior of the assembly shop.

One of the manager's chief difficulties was to obtain and train the necessary labour for the work, and in this connection it is interesting to note that at no time, since the factory was started, were there as many as 25 employees who had previously worked on the construction of aircraft. Yacht and boat-building yards in the neighbourhood were scoured for wood workers: a school was established for the instruction of women, who at the cessation

These machines measure 96 ft. from tip to tip of wings on a boat about 45 ft. long, the equipment being two Liberty engines, five machine guns, and two 270 lb. bombs. On October 12, 1917, lines for the first of these boats were laid down. Actual work on the boat commenced on October 17, and the keel was laid on November 2. The first boat made a successful trial flight on March 27, 1918, and was shipped from the factory on April 2. This was treated as a type machine, and work on it was so ordered that rapid production of the following boats would result. From April 1 onwards at least two boats were shipped regularly each week and the production of one machine per day was reached by June. On July 6, 1918, the last of the 50 machines comprising the first order, and the first of 100 similar machines comprising a new order, were shipped.

At the time the armistice was signed the factory had completed ready for shipment 150 of the H. 16 type and 33 of an improved type, together with 50 sets of spare parts for the original H. 16's. In addition, four experimental machines had been constructed, and the total value of the work done at the factory was estimated to be 5,435,000 dols. At that date, November 11, 1918, the total programme completed and in hand was for 830 twin-engine flying boats, which, with their spares, would represent work of the value of 23,240,000 dols. done at the factory.

Admiral D. W. Taylor and his assistant, Commander J. C. Hunsaker, of the United States Construction Corps, are to be congratulated on the output of aircraft for the American Navy. Commander F. G. Coburn, of the Construction Corps, was appointed manager of the factory at Philadelphia; although without experience in the manufacture of aircraft, he had managed with considerable success industrial departments at various navy yards, and the good results obtained at the works we have described showed the appointment to be a particularly happy one.

INTERNATIONAL ENGINEERING INTERESTS IN CHINA.

THE partial revival of American interest in China's possibilities, due to lack of Western competition during the war, is not without significance to British engineers, as the geographical position alone of the United States is a great factor in her favour. Further, it is possible that those now in charge of American interests in the Far East may profit by the lessons learned from failure, owing to lack of tact and appreciation of things Chinese, which has characterised some of their ventures up to date. These factors, coupled with the inclusion of China within the scope of the Monroe doctrine and the undoubted popularity of the United States in China, may make the American manufacturer a very formidable competitor.

Up to the year 1898, because of the decline of their mercantile marine, American interests were practically confined to the protection of missionaries. Peary's expedition to Japan revived a flickering interest in the Far East, but this was very short-lived, and nothing was done in China until the formation of the American China Development Company, which obtained in 1898 the concession for the construction of the Canton Hankow Railway. The terms obtained from China were singularly advantageous, but in spite of this the venture was a decided failure, and the only result was great loss of prestige and popularity.

The terms of the agreement were for a loan of 8,000,000*l.* at an issue price of 90*l.* per cent. bearing interest at 5 per cent., to run for fifty years. The bonds were secured on the property and the expenditure was entrusted solely to the company, who also received a commission of 5 per cent. on all materials bought. Further, the company was to receive 20 per cent. of the net profits of the line for a number of years. These terms are the best ever granted to a foreign power. The concession was obtained in the face of active opposition on the part of Belgium, representing, as usual, French and Russian interests, and this opposition was continued after the signing of the agreement, and took shape in an attempt to undermine American interest by purchasing a preponderance of shares in the open market. This procedure succeeded for a short time—long enough to admit of the supersession of the existing president of the company by the agent of the Belgian syndicate in New York. This resulted in a change of policy, and the China manager of the concern and the engineers in China were recalled and replaced by Belgians. China then refused to recognise the Belgian character of the company and claimed that the agreement had been violated. Finally, as the result of the efforts of J. P. Morgan and Co., control passed again to American hands, and China was also assured at the same time by the United States Government that the American character of the concern would be maintained. As a result of these protracted negotiations several

months' delay followed, and all work in China stopped, American interest in the scheme flagged, and Chinese discontent grew, so that China insisted on cancellation of the agreement. After lengthy negotiations America finally consented to abandon her rights for 1,350,000*l.* In this amount is included a sum of 600,000*l.* paid for work carried out by the company in China. This included 30 miles of completed line—the branch line from Canton to Samshui—and about 50 miles of completed earthwork on the main line from Canton to Hankow. It is thus seen that America easily holds the record for expensive railway construction in China. Moreover, the class of work done by them does not bear comparison with that done by British engineers, who also were without previous Chinese experience—though why men without such experience were chosen is a mystery—on the much-decried Shanghai Nanking Railway, which cost about 10,600*l.* per mile.

From the history of the construction of this line as given in a report by the American engineer-in-chief, costliness of construction would be expected. For instance, it is stated that, except for earthwork, operations are more economically carried out under the supervision of foreign foremen and that the wheel-barrow and tip-car are more efficient than the innumerable coolie and his basket and shovel for loads greater than 100 cubic ft. Steam pile drivers were also introduced on this short length of 30 miles. It can only be said that these conclusions are contrary to British and other experience in the country.

As a result of breaking the Chinaman to the wheel-barrow the earthwork in banks from 4 to 5 ft. high cost from 2d. to 3d. per cubic yard, or about twice the normal rate. Rock prices were in proportion, as was also the cost of concrete in place. At the time of closing down in 1904, 30 miles, 10 of which were double-tracked, were handed back to China. Of this the first 10 miles had a 31 ft. formation laid with 75 lb. rails on steel sleepers, and was fully ballasted with stone; the last 20 miles had an 18 ft. formation, laid with the same weight of rail on Japanese sleepers on sand ballast. The stations were matsheds, with the exception of that at Canton, which cost about 1,500*l.* In addition, China had the advantage of the information gained in the reconnaissance survey* made by the Development Company in 1898. The rolling-stock handed over consisted of eight second-hand locomotives and twenty 40-ton flat cars.

Altogether neither the finance nor the engineering of this scheme were a triumph for the United States. Further, judging from the fact that all materials bought for this line were American in origin, no great efforts were made to set an example in the manner of handling the Open Door policy which the United States has so consistently advocated. As a result of the redemption of this concession, Great Britain acquired her rights in the Canton-Hankow Railway, now under construction.

Following this unhappy venture, America acquired rights together with the British for a first option on any loan contracted for the construction of the Hankow-Szechuan Railway. This was in 1904, but in spite of the repeated invitations from British capitalists in 1905, and later by an Anglo-French group, to begin negotiations for floating the necessary loan, American capital was unable or unwilling to take any interest in the scheme. Then, as a result of German duplicity in demanding a share in financing this line, the United States found that her rights in it would be ignored unless insisted on. This was done in June, 1909, and resulted in the Four Nations Group Loan for 6,000,000*l.* for the construction of the above railway and the Canton-Hankow Railways. This money was to be equally divided between the nations concerned—that is, Great Britain, France, the United States and Germany. The terms were those initiated by the Germans with Germany having disastrous results in the case of the Tientsin-Pukow Railway—the fatal policy of relaxation of supervision of expenditure, a policy apparently endorsed by the United States, whose faith in the supposed great change which took place in the conduct of affairs at Peking as a result of the passing of the Empire is, to say the least of it, extraordinary.

As a result of this eleventh-hour decision to insist on her undoubted rights America had to be content with a third share instead of a half, and she is thus involved with us in the disgrace attendant upon Germany's diplomatic triumph. Our defeat was due in great part to German control of our finance, and one wonders whether similar causes contributed to that of the United States.

This railway is under construction, but work on all sections has been stopped since 1916 owing to the war. By the loan agreement all the nations concerned were allowed to compete for supplies to both this and the Canton-Hankow Railway, with the result that much of the steel work and practically all the locomotives and rolling stock for the 200 odd miles of the latter line now in operation came from America, as other nations were not in a position to compete. This, with the exception of a small colliery line 70 miles long in the Hankow district, constructed by American engineers in 1899 for Chinese capitalists, and now under Sino-Japanese control is, up to date, the total of American effort in which anything has been achieved.

America's railway and finance schemes in Manchuria, so far abortive, may now be dealt with. These schemes have always rested for success on the assumption that treaties made by Japan and Russia were binding, an assumption shown to be unjustifiable, unless their fulfilment was found to be expedient. All the schemes hinged on the clauses in the Treaty of Portsmouth, whereby Japan and Russia agreed on the principle of equal opportunity for all in Manchuria and of avoiding hindrance in any way of arrangements made by China for its industrial development. On this account the schemes came to nothing, for this treaty has been repeatedly violated to the detriment of both America and Great Britain. Nothing but an uncompromising attitude will convince Japan of the necessity of observation of treaty rights, and now if ever is the time for both nations to take up that attitude, or Japan will have failed to learn the great lesson of the war, and may thus be the cause of another.

These schemes began with the conclusion in 1905 of an agreement between Japan and E. H. Harriman, the American railway king, for joint ownership and working of the South Manchuria Railway and the various mining concessions acquired from Russia as the result of the Portsmouth Treaty. Japan on second thoughts came to the conclusion that she would prefer absolute control in Manchuria, and so, in order to nullify the above agreement, induced China to refuse to ratify the admission of American capital, the excuse advanced being that China wished to co-operate with Japan. This is typical of Japanese and Chinese diplomatic method, and should have been a warning. As a result, China, of course, did nothing towards finding capital, and Japan borrowed 12,000,000*l.* in London for reorganisation purposes. America benefited from Japanese* rolling stock orders, for, in the usual way, British capital was lent to benefit foreign industry, but her chance of controlling Manchuria was lost—a great misfortune which Washington and London might perhaps have prevented had our finances been under better supervision.

In 1906, following Russian loss of faith in her Far Eastern aspirations, the officials of the Chinese Eastern Railway, the Russian-owned railway connecting with the South Manchurian line, approached American capitalists to try and arrange a sale, and desultory negotiations were carried on until, in January, 1910, the American diplomatic blunder over the neutralisation scheme precipitated the Russo-Japanese entente with regard to Manchuria and finally settled the fate of that province in favour of the "might is right" party.

The neutralisation scheme referred to above was for the formation of an international syndicate to buy up and control Russo-Japanese railway and mining rights in Manchuria. The diplomatic blunder consisted, firstly, in choosing an inauspicious moment for the promulgation of the scheme, secondly in not submitting the scheme to the Powers principally concerned, namely, Russia and Japan, and, lastly, in the suggestion that if the Powers were unwilling to finance this scheme they should then find the money for the Anglo-American Chinchou-Aigun Railway, which runs parallel to the South Manchuria and Chinese Eastern Railways, and would thus compete with these lines to a certain extent. Naturally, when Japan and Russia heard of the scheme they combined to upset a project which was aimed at the destruction of their illegal special rights in Manchuria, and in this they were successful, owing to our strict adherence to the terms of our alliance with Japan, until August, 1914, a treaty one-sided and purposeless since the Russian defeat in the Japanese War. This diplomatic blunder is much to be regretted, as it revived Russian faith in her Far Eastern Empire and committed her to another era of expansionist policy there. This was the last thing the United States desired, for up till then there had been a very considerable Russian party in favour of the sale of the Chinese Eastern Railway, and this party might otherwise have succeeded in its aims. It should be stated here that every effort should be made now to prevent this railway falling into Japanese hands and to preserve the *status quo*, which is what America tried to get, namely, international control. This line is about 147 miles long, taps the most fertile part of Manchuria, the home of the soya bean—the trade in which is worth some 6,000,000*l.* annually.

Other American schemes date from the appointment of Tang Shao Yi, an American-educated student, as governor of Manchuria in 1907. He made every effort to encourage Anglo-American capital in the province in order to assert China's rights as defined by the Treaty of Portsmouth. With this aim in view a project was arranged for the creation of a Manchurian bank to be financed by America. This bank was to act as the financial agent of the Manchurian Government in the development of the province, and the first scheme to be put through was the construction of the aforementioned Chinchou-Aigun Railway, in which the British railway contractors Pauling and Co. were to co-operate.

The initial steps in the scheme were somewhat delayed owing to money difficulties in America, but in 1908 the United States Consul in Mukden went to Washington with a memorandum signed by the Viceroy of Manchuria, which was to form the basis of negotiations for a loan of 20,000,000*l.*, which was to found the Bank of Manchuria. Simultaneously an agreement was concluded with Pauling and Co., the British contractors, for the construction of a railway running southwards from Tsi-Tsi Har, a city just north of the Trans-Siberian Railway, to Chinchou on the Peking-Mukden Railway, the extension of the line to Aigun being undertaken by the Manchurian Bank. This agreement was ratified by the Viceroy of Manchuria in October, 1909, and was sanctioned by Imperial edict in January, 1910, the final detailed agreement being completed in the following April.

Further than this the scheme could not progress, for Japan and Russia both considered it as an encroachment on their special rights, and immediately protested, and at the Empress's death in November, 1900, Yuan Shih Kai's pro-American foreign policy was reversed to become pro-Japanese, so that the essential Peking support was also lacking. Since then nothing has been done except that American and British rights have been infringed in the matter of this agreement by the Japanese, by a loan agreement for a railway tapping the country traversed by the proposed Anglo-American line. The settlement of this question, together with the whole Manchurian question, should be of first-class importance to the two nations most concerned in the maintenance of the Open Door in this region. Now is the time to settle the question once and for all.

Following this set-back American railway schemes lay dormant until 1916, when the International Corporation asked China for an agreement to construct 1,500 miles of railway and to reconstruct the Grand Canal. China, in accordance with its usual muddle and drift policy, and hoping for some

* From Canton to Hankow.

* Practically all the rolling stock and steelwork for the reconstruction of this line was purchased in the United States with the proceeds of this loan.

sort of profit from the international squabbles bound to result, agreed, and authorised the Corporation to issue 5 per cent. guaranteed bonds redeemable in fifty years to finance the scheme. The railway first given to the Corporation was the extension of the Peking-Kalgan line westwards to Lanchowfu, the capital of Kansu. This proposal met with a storm of Russian opposition and was abandoned, and rights were then given to supply the province of Kianghsi with a railway system. This idea met with the same fate, as it infringed French rights. China then showed its contempt for Great Britain by giving the Corporation the right to build the extension westward of our concession, the Pukow-Sinyang Railway. Whether we should have eventually allowed this infringement of our rights is a moot point, but the fact remains that American survey parties were allowed to work on this route for eight or nine months and that the American chief engineer was kidnapped by brigands in 1918 while working in this region. At present the scheme is in abeyance owing to financial difficulties connected with America's participation in the war.

With regard to the Grand Canal portion of the scheme, Japan protested that this infringed her special rights in the province of Shantung, and as a result was admitted on terms little short of equality in the loan for 1,200,000*l.* to be floated to finance this scheme. This, of course, was tantamount to admitting these special rights—a great diplomatic blunder apparently condoned by the other Powers. Japan, of course, immediately made her rights doubly secure by advancing 100,000*l.* in November, 1917, for investigation purposes.

Throughout, these negotiations appear to have been characterised by a blundering lack of appreciation both of the methods of Eastern diplomacy and the intricacies of the railway situation in China. Further, the terms under which the money was to be advanced were those initiated by Germany and perpetuated by Japan in a manner which should have been an object-lesson to all.

Lastly, in the field of mineral exploitation and development the Standard Oil Company of New York acquired in February, 1914, a concession to exploit the oil resources of the provinces of Chihli and Shansi, the Chinese Government to receive 37½ per cent. of the capital of the Sino-American company to be formed after investigation of the proposed oilfields. These investigations were made and unfortunately proved disappointing, with the result that the concession was abandoned on expiry of the option in February, 1915, as the Chinese refused to extend the concession area to the whole of China, as desired by the company.

This completes the summary of the efforts America has made towards China's development, and it cannot be said that they have been particularly successful. However, in the machinery market it is quite another story, for here American popularity is a great asset and diplomatic difficulties are absent.

The reasons for this good feeling between the two countries date from the Russo-Japanese war, when America rendered great service to China in limiting the area of hostilities and in fighting for Chinese rights at the treaty of peace. In addition, nearly half of the American share of the Boxer indemnity—about 5,000,000*l.*—was remitted in April, 1911, China undertaking to spend the money thus saved in educating students in America and founding a college in Peking for preparatory purposes. This, combined with the very large missionary educational effort, is a great factor in spreading American ideas, which as a rule do not err on the side of self-depreciation. Further, the great philanthropic work done in China by the American Red Cross and the Rockfeller Institute has tended to foster goodwill. The work of the Red Cross in China is particularly calculated to appeal to the Chinese, for in the famine of 1911 and 1912 in Northern Anhui and Kiangsu Red Cross relief work saved thousands of lives and also did useful work in dyke conservation. In 1914, too, a board of engineers appointed by the same society visited the affected districts and evolved a comprehensive scheme for flood prevention in this district. As a result of this the American Red Cross was empowered to raise 4,000,000*l.* at 5 per cent., to be secured on lands to be reclaimed and on Grand Canal dues, for these conservancy works. Owing to the war the option for this loan was extended to January, 1915, when it expired, to be taken up later by the International Corporation aforementioned. An added reason is the persistent championship of the Open Door policy and the maintenance of China's integrity, and perhaps, above all, the childlike faith in the ability of China efficiently to manage her own affairs, which soothes official vanity in Peking. These reasons, coupled with the unquestioned ability of American agents, the activity of her consuls, and lack of competition during the war, have given America a long start in the Chinese machinery market. As a result of the war her only serious competitor at present is Japan, and in the locomotive and rolling stock market she holds a monopoly, for since 1915 only American goods have been obtainable. America is therefore in the position of the man in possession of a market which should be worth fighting for, for the rolling stock situation in China needs immediate attention.

In 1915, the date of the last comprehensive railway report, the mileage of government railways was 5,444 and the number of goods cars 10,562, or 1·93 per mile. The number of engines was 638, or 0·116 per mile, and the average number of trains per day 6·5. In India a railway with a similar number of trains per day is equipped with 4·65 wagons per mile and 0·14 engines per mile.

These figures are bad enough in themselves, but they do not nearly express the actual facts, for out of these 10,562 goods cars 3,600 are owned by the Peking-Mukden Railway, which is only 607 miles in length and has about six goods cars per mile and 0·253 engines per mile, and is thus equipped to Indian standards for about 11 daily trains. The equipment of the remaining mileage is therefore more than ever totally inadequate. Moreover, the Peking-Mukden Railway, owing to its large mineral traffic, is itself under-equipped, and this fact is retarding the development of the coal mines owned by the Kailan Mining Administration, in which British capital is very largely interested, and which are situated on and entirely dependent on this railway for transport. It is confidently stated that, given the facilities, this concern could increase its existing output of about three million tons by a further two million annually. Now, in 1915 the car capacity of this line was about 70,000 tons, and the tonnage handled in the year 5,349,223, so that it (the car capacity) was utilised about 76 times. Owing to the fact that the average haul per ton is over 80 miles, that the line is single track and has 85 lb. rails in the district of heavy traffic, it is very doubtful if much more can be got out of the existing rolling stock. The railway is therefore, unless double tracking is decided on, about 26,000 tons short of car capacity to handle the development of its coal traffic only, setting aside the development of other traffic, which has increased two million tons from 1913 to 1915.

Shortage of rolling stock is also hampering very seriously the development of the Peking Syndicate Mines, situated in Honan, on a branch of the Peking-Hankow Railway—a railway notorious ever since the outbreak of civil war for military interference. The Peking Syndicate is, of course, a British company, with a capital of 1,242,822*l.* In 1918 the rolling stock shortage became so acute that representation was made to the Allied Legations in Peking, but this was without effect, for since the beginning of the war the only purchases of equipment made have been about 20 locomotives from America, and the placing of order for perhaps as many more in the same country. Not a single car has been ordered, nor have the railway works in the country produced any, yet Japan was able to place orders for 25 locomotives and 1,000 car frames and bogies in America.

The government is thus without any excuse for hampering industry, in which British and other Allied capital is interested, and for the loss of the enormous revenue which would have resulted from properly equipping the railways and from efficient control of the army, which has disorganised the railways ever since 1916 and still continues to do so.

It is thus seen that for the equipment of the existing lines China should spend immediately an enormous sum of money—about 3,000,000*l.* For this order, as stated above, we have a very serious rival in America and also in Japan, for, as the result of certain loan agreements contracted since the war, China is forced to buy equipment for some railways from Japan. Similar conditions hold with regard to the machinery market and the electrical trade, but it is doubtful if Japanese competition is likely to be very severe for any length of time, for Japanese trade methods are as a rule their own downfall, and in many cases their work is inferior. It is to be hoped, at any rate, that British capital invested in China will insist on our fair share of this order, and not allow, as in too many cases in this country, our money to benefit foreign industry. One result to be hoped from the war is the development of the idea that the investment of British capital should imply benefit to British industry.* The absence of the German Jew element from boards of directors is essential to its growth.

With regard to the settlement to be made with Japan, and such settlement is urgently necessary in the interests of all Western nations concerned in the Far East, America has shown by her decision to rejoin the Four Group Loan organisation in 1917 that she means to take a considerable hand in the conduct of China's future finance. In order, therefore, to secure the integrity of China and also the Open Door, she should unite with Great Britain, whose aims have always coincided with those of the United States as to these two essentials. The next duty would be to force on China an international reconstruction scheme, the salient points of which should be:—

1. Army disbandment and reorganisation and the creation of a foreign officered gendarmerie.
2. International supervision of all new loan expenditure and loan allotment.
3. The creation of an international railway service, which should control all railway policy.

Only in this way will China's speedy development be secured and her future be safeguarded.

DENSITY AT ABSOLUTE ZERO TEMPERATURE.—In the beginning of 1916 R. Lorenz, of Danzig, published a series of papers in the *Zeitschrift für Anorganische Chemie*, vol. 94, on atomistics and the relations between the volumes of the same substance at zero temperature, at melting point and boiling point, and between the critical temperature and temperature of the boiling and melting points. The deductions were based on the rule of corresponding states, and Lorenz did not claim to obtain more than approximate values by applying his relations, which he tested by the experimental data compiled by himself and others. Thus, for instance, the ratio of the critical volume Vc to the volume Vo at absolute zero should be 3 according to Van der Waals, 4 according to Berthelot; Lorenz and others finding values between 3 and 4, Lorenz accepts 3·75 as average value. Similarly Vi/Vo (ratio of volume at boiling point to volume at zero) is, according to Lorenz, 1·41, and the ratio Vm/Vo (where *m* refers to the melting point) 1·21. There is also a definite relation between the volume at any temperature and the volume at the boiling point of the same substance. From these relations W. Herz has recently (*ibid.*, vol. cv, page 171, April 3, 1919) calculated the density, d_0, of various substances at absolute zero, taking the density as the reciprocal of the volume. It is certainly surprising that the d_0, calculated by those four relations, are in general in rough agreement. Thus Herz finds for the d_0 of oxygen by the five relations mentioned, 1·53, 1·60, 1·61, 1·55; for hydrogen he deduces from some of the relations 0·0987, 0·124 and 0·0927, for nitrogen 1·064, 1·137, &c.; for mercury the values lie between 16·5 and 17·9. The calculations of the atomic volumes at absolute zero are also interesting. But the general increase of the density at absolute zero d_0 with the atomic weight is more striking; the average values of the d_0 are: hydrogen 0·105, helium 0·18, oxygen 1·8, krypton 3, xenon 4·2, sodium 1·08, potassium 1·004, nitrogen 1·137, phosphorus 2·1, antimony 7·6, bismuth 12, fluorine 1·5, chlorine 2·2, bromine 4·2, iodine 5·2. Sodium, having a smaller atomic weight than potassium, does not fit into this arrangement, however, as its zero density is greater than that of potassium; but this peculiarity shows also at ordinary temperature, since sodium has the density 0·98, and potassium 0·86. According to Lorenz the volume actually occupied by the molecules at absolute zero should be one-twelfth of the natural volume.

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* It should be noted here that America, as the result of being Russia's creditor to the extent of £13,000,000 for rolling stock supplied to the Siberian Railway, &c. will naturally hold a superior position in the Siberian engineering trade as well.

PERCUSSION PLANT FOR OIL-WELL DRILLING.

OIL and bitumen in some condition are neither rare on our globe, nor limited in their occurrence to particular geological periods, divisions of the globe, local topographical features, or climates. The northern hemisphere seems to be favoured with oil; as to that, future generations may arrive at different conclusions. Yet the commercial oilfields appear to be restricted to two geological ages, the carboniferous and the tertiary, and a prospector would hardly venture at present on oil-drilling against the advice of geologists. What one geological expert would condemn as a wild-cat scheme, however, may find the approval of other experts, and the oil-boring operations now proceeding in Derbyshire have met with the decided support as well as with the disapproval of geologists. Whatever the outcome of these operations, nobody expected to find oil here in England at what would have been considered workable depths a few decades ago. In the 'sixties and 'seventies of the past century the average depth of oil wells was only about 150 ft., though the Chinese are credited with having resorted to power machinery in well-drilling before the Christian era. By 1900 the average depth had risen to 1,000 ft.; at present the average may be put at 2,500 ft., and that depth had considerably been exceeded in several of the new wells in the Midlands when oil was reported to have been struck at Hardstoft in the last week of May.

The well of Borysław-Tarnowice, in Galicia, was driven to 5,810 ft. before the war, and there are several wells more than a mile in depth. Such a development and an annual output of over 70,000,000 tons of oil (1917) necessarily imply highly-specialised mining systems and machinery as well as a tendency to deliver the control of the whole industry into the hands of powerful combines. Hand wells were still being worked in Rumania in 1916, in spite of their terrible dangers, by the side of plants equipped on the most modern systems of the percussion, rotary, hydraulic and combination types. Each of these systems requires its own type of rig. How materially the rigs differ, even of the several percussion systems, which are distinguished as American, Standard or Californian, and Canadian systems, and by other terms, was shown in a joint paper on "Plant used in the Percussion System of Drilling Oil Wells," which Mr. Maurice A. Ockenden, F.G.S., M.I.Mech.E., and Mr. Ashley Carter, A.M.I.Mech.E., presented to the Institute of Petroleum Technologists in March last. The pages of specifications for the several rigs, which Messrs. Ockenden and Carter added to their paper, might damp the enthusiasm of the inventor and of the enterprising man of small means. The paper and the specifications well set forth the actual needs of the driller, and they further put order into a special branch of engineering which an arbitrary nomenclature has rendered more difficult than it is in itself. We are indebted to Messrs. Ockenden and Carter for our illustrations of the present article.

Percussion or cable-drilling embodies the alternate dropping and raising of heavy tools. For this purpose is required a rig comprising power machinery, a derrick, cordage, strings of tools and wheels and other appliances for their operation. In their paper Messrs. Ockenden and Carter dealt more particularly with the tools and the development they have undergone. The terminology calls for some explanation, and we will briefly outline the method of operation with the aid of the diagram, Figs. 1 to 6, on page 831. These figures illustrate, in plan and elevations, plant manufactured by the Oil-Well Supply Company of Dashwood House, New Broad Street, E.C., and represent an all steel California plant, viz., built of structural steel.

The tools are attached to the drilling cable which passes over the crown pulley on the top of the derrick and is spooled on the shaft of the bull wheels (on the extreme right of Fig. 1). By raising the bull-wheel brake lever the cable is unwound from that wheel and lowered into the hole; the proper depth having been attained, the lever is forced down and the unwinding stopped. The pitman which works the walking beam is then raised, and its lower end is passed over the wrist-pin on the crank of the band wheel, which is the large wheel in the centre of Fig. 1; this wheel is driven by belting from the engine, and communicates power to the bull wheel through a rope or a sprocket wheel. The sand reel next to the band wheel, which has a line of its own, is driven by friction from that wheel. When the pitman has been fixed, the temper screw which is fastened to the other end of the walking beam, is attached to the drilling cable by means of clamps, and drilling can start. These remarks apply in the first instance to the working of the Standard rig which is common in the oilfields of the Eastern United States. When speaking in general of the American cable system, Mr. Ockenden means both the Standard rig and the Californian rig; the latter has all the features of the former combined with suitable attachments for handling the casing without disturbing the drilling cable. This is effected with the aid of the calf wheel which was introduced in California. The calf wheel takes the casing line which is spooled on its shaft; the line also passes over a pulley in the crown block, and is guided by sheaves. Fig. 1 shows three lengths of casing, held by the elevator, ready for lowering into the well. The Canadian system proper, to which we shall presently refer, is somewhat different, and is known also as the pole system. The Russian and Fauck "free-fall" systems, the third of the three recognised percussion systems of Messrs. Ockenden and Carter, may be traced back to 1843, whilst the American systems date from the 'seventies and 'eighties.

Passing to particulars and to power in the first instance we have to bear in mind that portable drilling rigs are to be complete in themselves, and must be fitted with substitutes for the derrick and various wheels, &c., mentioned. Portable machines of small size were used by the Allied Governments for well-drilling during the war. Semi-portable rigs enjoy favour in some fields of America where the rig can be delivered complete on the site, but are unsuitable for foreign fields where the rig must be dismantled and packed for transportation. Mr. Ockenden said little about power, steam, gas, electric, and engines, because that subject had been dealt with in other papers brought before the Institute of Petroleum Technologists. It is rather striking that internal-combustion engines are not used in the United States for drilling, though much natural gas is wasted; they are used, however, for pumping, swabbing, &c. The engine most in favour over there is the horizontal single-cylinder engine for up to 70 h.p., driven by steam from portable locomotive boilers.

The old derricks, built entirely of wood or bamboo, have the advantage of lightness, cheapness and elasticity. Angle steel derricks, introduced in the 'ninoties, were first made with panels 14 ft. to 17 ft. in height; that height is now reduced to 8 ft. During the last decade complete steel rigs, comprising walking beam, samson posts (for the beam), crown block, bull wheels, &c., have come into use. Mr. Ockenden did not consider it likely, however, that the steel rig would generally replace the wooden structure, though some steel rigs have drilled upwards of 20 wells. Tubular steel derricks, especially of the Neill type, offer the advantage of rapid construction, which Mr. Ockenden ascribes mainly to the use of forged steel (instead of cast steel) clamps. Our photograph, Fig. 14, on page 833, represents a Galician derrick, a modification of the Canadian type; the derrick is to be enclosed as a protection against the weather; in Canadian fields derricks are frequently left open. More crowded derricks can be seen in the background of the photograph. The crowding, a general feature in oil fields, is worse in Fig. 15, a photograph of a Burmah oil field, all operated on the American cable tool system; the sheds leading away from the derricks contain the engines, belting, wheels, &c., mentioned.

The ropes and cordage, by the aid of which the rig is suspended, form a very important item of the equipment. Wire rope can, in wells with high-level fluid, be used with much greater ease than manila cable, and its use also originated in California. The American drawn wire being then found unsuitable for drilling, English drawn wire was imported into America and fabricated into rope, and then shipped from there to other oilfields. Much cable is damaged and wasted during fishing operations; discarded wire rope has little value. In the deepest Galician well, Mr. Ockenden mentioned in this connection, a commencement was made in the dry with manila rope; later metal was adopted, but 10,000 ft. of tapered wire, and, further, 5,000 ft. and 7,000 ft. of wire rope could only be used for one day in fishing. The chief parts of the cordage are the drilling cable, the casing line and the sand line. All the lines are supported by the pulleys of the crown block (see Fig. 5). The large crown pulley in the centre supports the drilling line; the small central pulley is the sand line sheave; the four pulleys outside bear the casing line. On Pennsylvania derricks, when no special arrangements are made for the suspension of the casing, the number of pulleys in the crown block is reduced to two. When the hole becomes filled with water and mud, a bailer is attached to the sand line; a bailer is, *e.g.*, a pump barrel, fitted with a valve at the bottom from which a "dart" extends downward; when the dart strikes the bottom, the valve is raised and the water—which may also flow in at the top—enters the bailer. The sand pump is a bailer provided with a plunger; but these bailers and pumps vary much in construction and in the mechanism for their emptying.

Some of the modern tools seem less to fit their names than the old tools from which they have been developed. The general tendency has been towards rigs of heavier weights. About 1880 bits of 30 in. length were used for holes 3 in. in diameter; the weight of the entire "string of tools" did not exceed 300 lb., whilst now the actual ordinary string of tools weighs about 1¼ tons and the commencing string 2 tons. Mr. Ockenden gave the following table of sizes and weights of American rig-irons:—

Sizes.	3½ in.	4 in.	4½ in.	4¾ in.	5 in.	6 in.	7½ in.
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Standard ..	1,584	2,352	2,666	2,697	2,919	—	—
California ..	—	—	4,766	—	4,828	—	—
Ideal California ..	—	—	—	—	7,451	7,879	13,214

The parallel joints of the early practice were the cause of much trouble, as they became worn from frequent making and breaking, screwing and unscrewing. The later taper joints were a great improvement. At present every tool is fitted with box and pin at both ends; the pitch of the thread is 7 or 8 to the inch, and the pin is machined either with V or with flat thread. The paper specifies the dimensions of the joints and of their square wrenches and the diameters of the box and pin collars, for American cables, as well as the standard sizes of drill joints for Canadian pole tools.

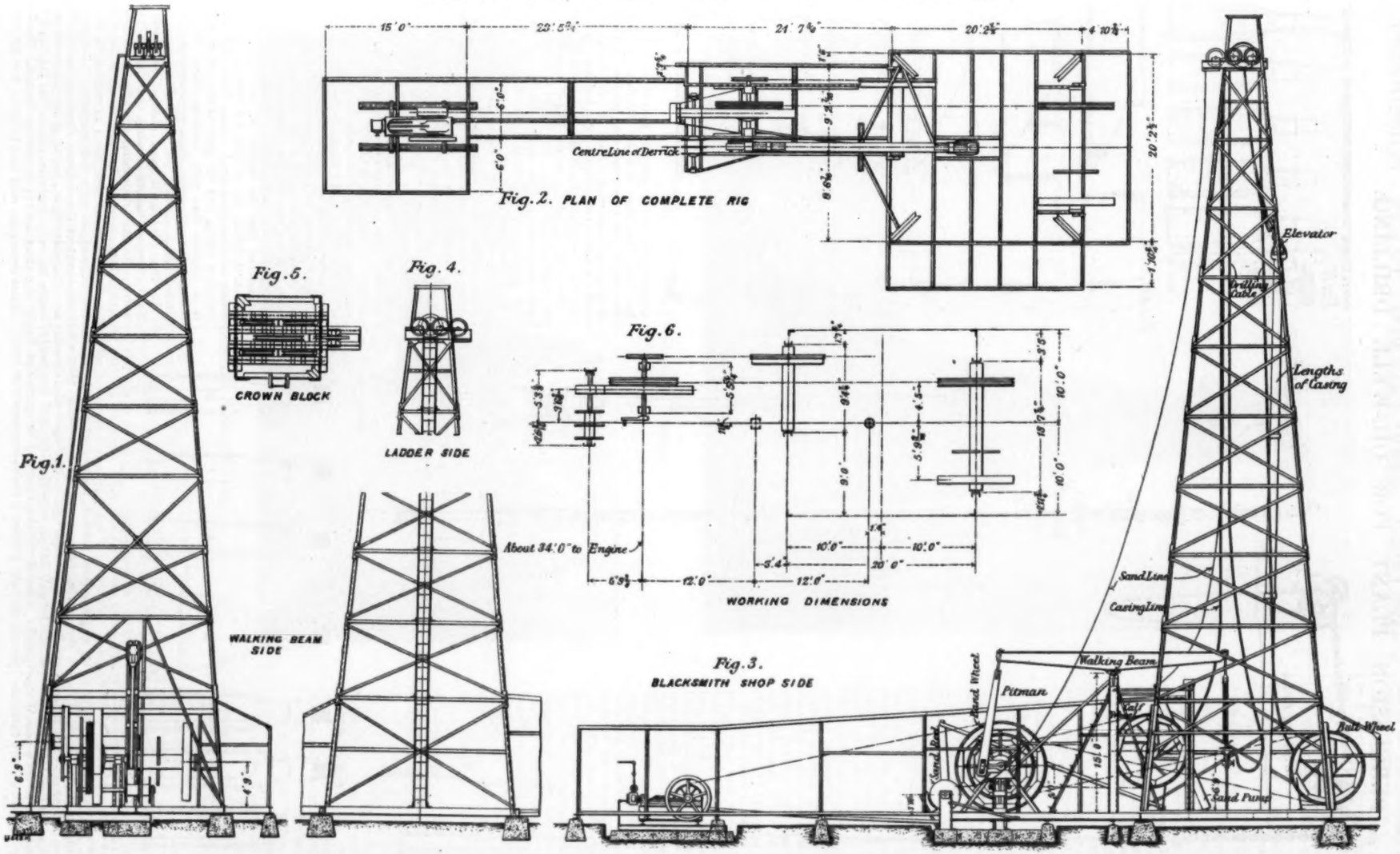
The temper screw which serves for adjusting the length of the line was in the old days a ¾-in. V-thread, measuring about 3 ft. over all; at present the screw has a diameter of 2 in. and a let-out of 6 ft., and it is fitted with ball bearings.

The three strings of drilling tools, illustrated in Figs. 7, 8 and 9, page 832, exemplify strings of American and Californian tools, Canadian pole tools, and Russian free-fall tools, as suspended from the walking beam. The first of the four specifications which Messrs. Ockenden and Carter had added to their paper is the specification of an American Standard cable rig for 2,000 ft. as adapted for work in formations free from caving tendencies or in which the handling of casing of pipe is not a serious problem at any rate. This rig makes use of Standard drive pipes and casing. The Standard tubular derrick would have a height of 72 ft. and more on a base of 20 ft. Their American-Californian rig for 4,000 ft., to which the second specification refers, is much in favour for pioneer work. As drive pipe and ordinary casing will not withstand the strain of surging or working in long strings in soft formation, California type of casing is made use of, and the rig-irons are not infrequently increased to 7½ in., for greater depths.

In Fig. 7 (American rig) A is the temper screw, connected at B with the cable. The connection of the cable with the rest of the drilling line is effected by means of the rope socket C; swivel connections may also be resorted to. The sinker bar D is to give increased power to the blow of the jars E when working in heavy clay. The jars, which are likewise used in pole-tool rigs, but are not needed for free-fall systems, consist of two links forged from a solid piece of special steel, with box and pin joints. The device is wanted to jar the string of tools loose and to liberate the drilling bit when stuck in the hole. While drilling, the jars are placed between the rope socket and the stem; for fishing operations it may be necessary to fix them below the stem, immediately above the fishing tool. The stroke of the American drilling jar is 4½ in.; that of Canadian and Galician tools 6 in. to 8 in.; fishing jars may have strokes up to 60 in. Like the bits, the jars, Mr. Ockenden remarked, are frequently abused by inexperienced drillers. The drill stem or auger F is a solid rod like the sinker bar, but of several times its length, forming an essential part of the outfit. Fishing tools, not marked in the diagrams, and fishing operations, Mr. Ockenden stated, might well form the subject of future papers, and that suggestion found support in the meeting. There are numerous and manifold devices for recovering damaged and lost tools, for cutting and removing defective casings, for picking up dropped tools, strings and tangled ropes, and though fishing is regarded as part of the training of a first-class driller, experienced "fishermen" frequently take entire charge of difficult operations. Various kinds of slip sockets and horn sockets have been used for fishing; magnets hardly answer in small holes, and many new devices fail to accomplish what they are recommended for. Further references to Figs. 8 and 9 will be made in due course.

Particulars of bits, G in Fig. 7, H in Fig. 8, and J in Fig. 9, are given in Figs. 10 and 11. The selection of the bit is governed by the system and the formation. In cable drilling through shale, limestone or sandstone, the cutting edge is dressed more or less to a chisel point; for softer clays, shales, and for sands, the centre of the bit is hollowed out, making a concave face. In sandy and soft formations a chisel edge will enter faster than the drillings can be mixed with water, and re-drilling has to be adopted to form a slurry for quick removal. Some operators desire thick, wide bits with wide backs, others wide bits and hexagonal backs; some prefer thinner bits of smaller width with plenty of clearance. For deep drilling large bits, 7 ft. or 8 ft., not rarely 11 ft. in length, are becoming general in

PERCUSSION PLANT FOR OIL-WELL DRILLING.



America. In Fig. 11, No. 1 represents a regular spudding bit, that is to say, the bit which is used in commencing drilling operation with the aid of the bull wheel and sometimes of a special jerk rope. No. 2 is the ordinary American pattern, dressed at the edge to requirements. No. 3 is the "Mother Hubbard" bit, showing cutting edges on the shoulder; it is usual to dress the bit so as to obtain a slight clearance with a concave cutting edge. In No. 4, the long-shank California bit, the shoulders are always sloping; the deep waterway is carried right up to the wrench square and dressed to give plenty of clearance; the tapered shoulders enable this bit to work immediately below the casing shoe for which the "Hubbard" bit, No. 3, is not suited. Diagram No. 5 exemplifies the typical Russian bit (see J, Fig. 10) with guide attachment for the reamers and undercutters. No. 6 is the regular Canadian tapered bit; No. 7 shows the eccentric bit in use for pole tools (compare H, Fig. 8) on the Canadian-Galician system; it is used to a limited extent also in California. The star bit (No. 8) is much favoured in Russia and Rumania for truing or rounding flattened holes, but is not commonly used with American tools. Since holes are never quite true, we might mention, a 13-in. bit would be used when a 10-in. casing is to be put in and a 10-in. hole for 7½-in. casing.

With a view to economy it used to be the custom, Messrs. Ockenden and Carter stated, to draw the long bits out and to forge them into smaller sizes; the present practice makes use of bits for one diameter only, until they are worn out. Especially for foreign service a knowledge of heavy smithing is absolutely necessary for those responsible for dressing the bits; the diagrams in Fig. 1 of defects due to improper dressing of drilling bits, were exhibited to urge this point. Bits dressed with an uneven edge, as in A, frequently break at the pins and even break off in the wrench square. The results of improper heating and tempering, common practice unfortunately, are exemplified in B and C; large bits are not turned after placing them in the fire, as they should be, and may hence crack after tempering. The cause of the fracture in D is too hard tempering, and the defect would have

PERCUSSION PLANT FOR OIL-WELL DRILLING.

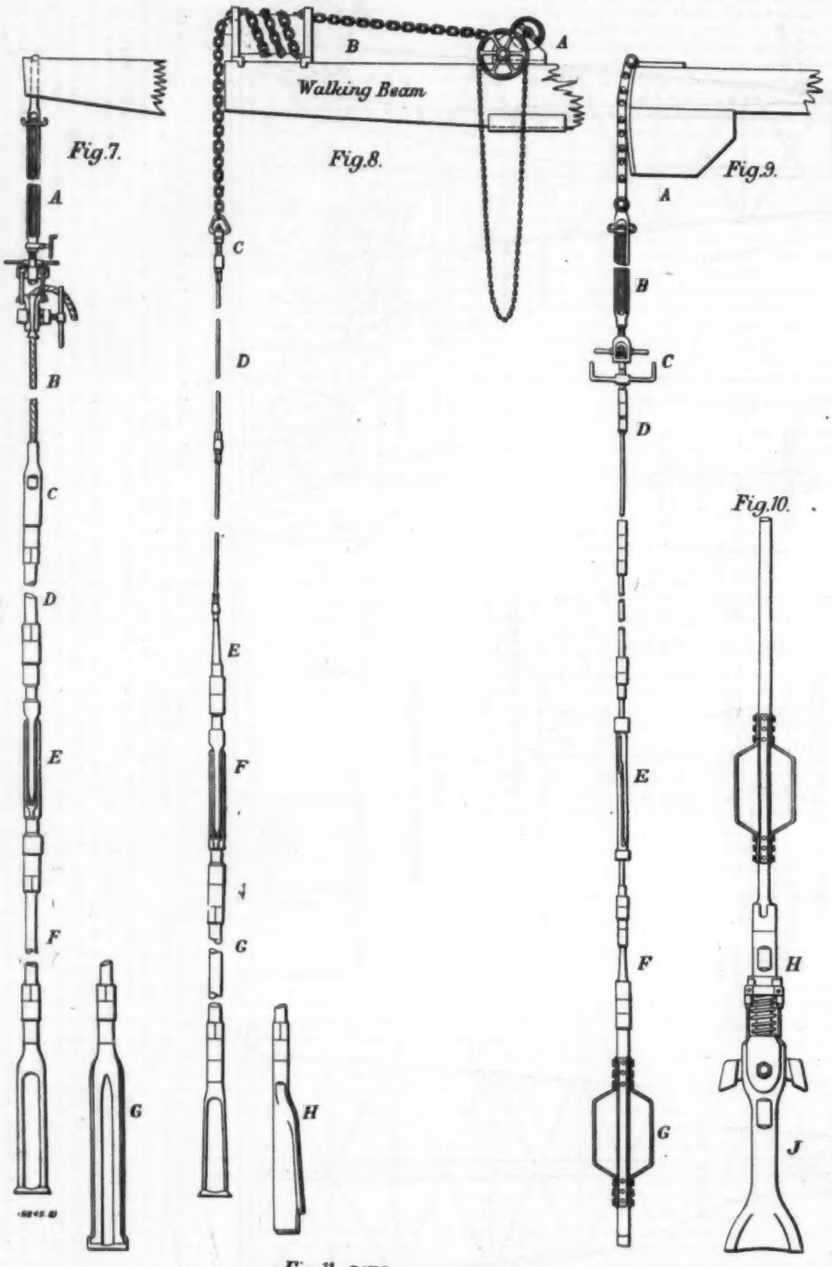


Fig.11. BITS.

DEFECTS DUE TO IMPROPER DRESSING OF DRILLING BITS.

Fig.12.

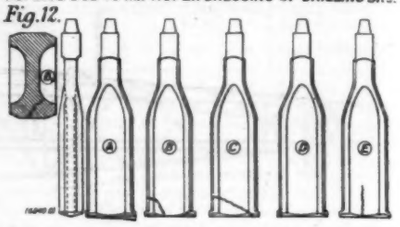
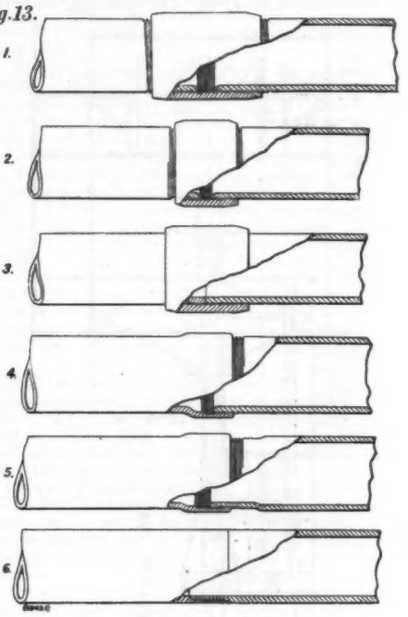


Fig.13.



to be cured by re-forging. The fracture in E, a crack running from the cutting edge up to the centre of the water course, is not common and indicates piped steel; the defect should be rare since the steel billet is worked and tempered at the opposite end to the pipe. When steel billets sufficiently large to make a heavy California bit weighing from 1,500 lb. upward are directly placed in the heating furnace without preheating, they are apt to crack. Large bits to be forged and dressed should be put into a very slow fire and frequently turned; care should be exercised in particular to prevent the light portion of the water course from being more rapidly heated than the heavier portion forming the web. Eccentric bits are fitted with one web. Bits of T and I sections also require very careful forging and tempering; such bits are more common with Canadian and Galician rigs, but heavy eccentric bits have been introduced also in Californian oilfields.

The term "casing" covers all pipes used in lining the walls of a borehole. The question of casing is of such importance and its varieties in joints, threading and weights are so wide that Messrs. Ockenden and Carter could not do more than refer briefly to these problems. Every well requires some casing in its construction; the quantity and number of strings varies with the depth, the irruption of water and the caving troubles. Three categories may be distinguished: (1) Casings in which a coupling or collar is used, and casings the lengths of which are (2) screwed into one another, or (3) riveted together. In the "drive-pipe" the casing is screwed to butt in the couplings; the full area of the metal of one length is in direct contact with the full area of the metal of the adjoining length. In common practice drive-pipes are used only for the larger sizes. The drive-pipe joint, screwed with a thread to meet in the centre of the coupling, cannot be made sufficiently tight to withstand the great pressure of gas and water met with at low levels. Hence deep drilling with great pressures has developed special casing joints. Standard casing is so constructed that the lengths do not butt together, and is, therefore, not suitable for driving. California casing couplings are much longer than those of the Standard casing, and the pitch of the thread is finer. It is obvious that with couplings fewer strings of casing can be telescoped than with inserted joint or riveted casing.

In Fig. 13 some typical casings are illustrated. No. 1 refers to the long coupling or California type of casing; the chief dimensions are: 6⅝ in. diameter of casing, 7⅜ in. length; diameter 8¼ in., 10 in., 12¼ in., length 8½ in.; diameter 15¼ in., length 9½ in.; there are 10 threads to the inch throughout. The diameters and lengths of the ordinary Standard casing, No. 2, are: Diameter 6⅝ in., length 4⅜ in.; diameter 8¼ in., length 5½ in.; diameter 10⅝ in. to 15¼ in., length 6½ in.; there are 11½ threads to the inch. No. 3 is a regular drive-pipe, ends butt to butt; it is not suitable

PERCUSSION PLANT FOR OIL-WELL DRILLING.

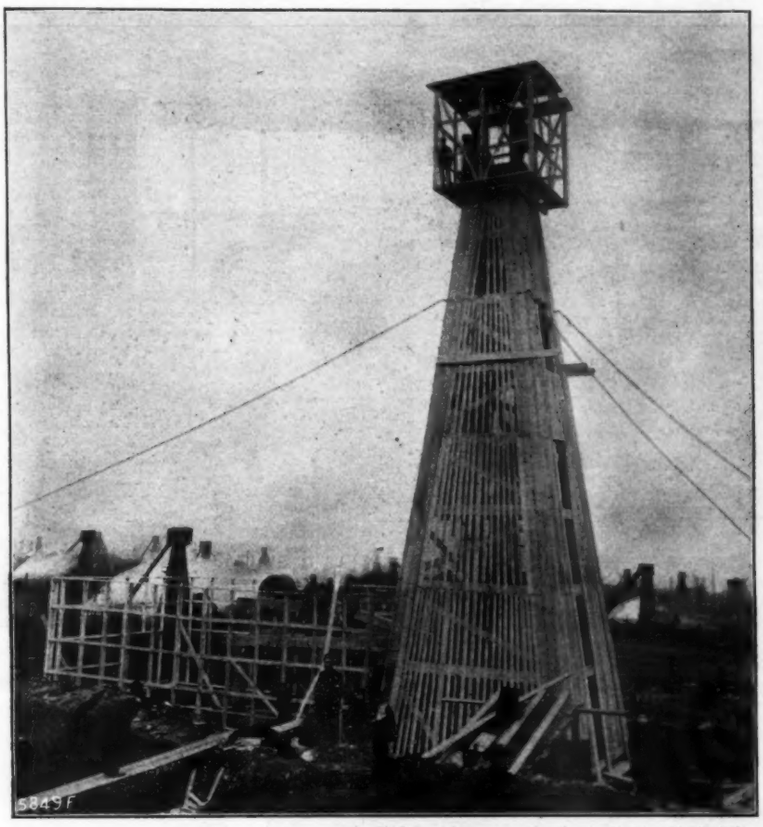


FIG. 14. 4,000 FT. GALICIAN DERRICK.

FIG. 15. TYPICAL VIEW IN THE BURMAH FIELDS.

for surging in long strings. The inserted-joint casing, favoured by Canadian and Galician drillers, is illustrated in No. 4; this casing, Mr. Ockenden mentioned, may in the near future be used to greater extent with other systems, because a larger number of reductions is possible than with collared casings. The two remaining diagrams exemplify types which are not practicable for oilfield use. No. 5 is a swelled and creased joint; the internal reduction prevents the insertion of full-diameter tools, and owing to the rapid movement of cable tools, no obstruction or variation in internal diameter is desirable. The flush-point pipe, No. 6, finally is used for core drilling, but is not suitable for oilfield work.

Advantages are claimed for the Canadian or pole-tool system for drilling in soft formation, and it has been extensively adopted in Europe and in certain other parts of the world. The rotation of the pole prevents the hole from becoming "flat" or crooked. A larger drilling staff is required, but the men need not be so highly skilled as for the more rapid systems.

Tubular derricks are made more than 60 ft. in height with an 18-ft. base. Returning to Fig. 8 we see that the main parts of the rigs are: A and B, slipper out and chain; C, swivel adaptor; D, poles, made of ash or iron; E, adaptor; F, jars; G, drill stem; H, regular or eccentric bit.

Specification 3 of Messrs. Ockenden and Carter refers to a Canadian Standard rig for 2,000 ft. Specification 4, for a Canadian-Galician rig for 4,000 ft., is a typical specification of the rig as used in the Galician oilfields at the outbreak of the war, and it was drawn up with the assistance of Mr. Albert Millar, who had many years' experience in Galicia. The derricks were mostly built of local timber, but steel and tubular derricks will probably find their way into those districts. The pipe used in Galicia is of the inserted-joint type. Austrian standard.

As regards the Russian free-fall system, Messrs. Ockenden and Carter hesitated to submit a detailed specification since many modifications have been adopted within recent years, and since they consider it highly probable that other systems will eventually be introduced. The tools, weighing about 1½ tons, are all connected by square iron rods to the temper screw and walking beam; the rods are usually 21 ft. long and 1¼ in. square. The walking beam operates the rig machinery as usual; a second hoist or drum controls the sand pump, a further drum the casing; a larger staff is required than with the California rig. In our diagram, Fig. 9, of the Russian free-fall rig A indicates the flat link chain, B the temper screw, C the swivel, D the poles and E the free-fall machines; lower down follow the adaptors F, the sinker bar and guides G, the under-reamer H, and the drilling bit J. The free-fall mechanism E operates as follows: The rods with tools attached are first attached to reach the bottom of the holes. Each downward movement produced by the walking beam causes a spindle inside the free-fall device (to which are attached the under-reamer and bit) to engage with a projection on which this spindle is allowed to rest during the upward movement. By rotating at the temper screw the spindle (with under-reamer and bit) is released and falls free of the main string of tools, the drop amounting to about 4 ft. The mechanism engages again with the spindle on the upward movement. Owing to the cumbersome gear used in Russian wells on this system and the large diameter of the holes drilled, fishing operations present serious problems and greatly retard progress, and the cost and speed of drilling compare unfavourably with other recognised systems.

Fishing difficulties, as we said above, are serious everywhere, and though drilling when steadily proceeding is monotonous, diversion is never absent for long periods. Many of the ordinary operations call for unusual strength, skill, quick decision, and common sense, and it is for these reasons that, however good the design and construction of a plant, the ultimate success of oil mining will very largely depend upon the competency of the staff, especially in pioneer work. It is not astonishing either, that it is not the trained engineer who succeeds best in the oilfield. Men are selected, as Messrs. Ockenden and Carter stated, for their good judgment, blended with courage and caution, who can in trouble exercise ingenuity, patience and initiative. Englishmen have not taken seriously to this class of work, probably because there have been in the past insufficient means for home training and little inducement to the younger men to go abroad in a minor capacity.

Mr. Ockenden quoted in this respect a remark from Mr. Dalton's "Technical Investigation": "Productive oilfields are necessary for the desired purpose of education." There is an absence of superficial finish and display in the oilfield equipment which is countenanced by the mining engineer. College training is, of course, essential. But we should like to repeat in this connection, what we have said on other occasions, that too much reliance should not be placed upon the specialised technical college and upon splendidly-equipped laboratories, where everything should go right. Trouble is almost the rule in the oilfield. Laboratory practice will not enable the engineer to fish out a tool from the bottom of a well, or to stop a dangerous rush of gas, water or oil, and a college diploma does not entitle the young engineer to the salary of the experienced driller.

POCKET AERONAUTICAL DICTIONARY.—We have received from Messrs. Sampson Low, Marston and Co., Limited, a copy of Jane's Pocket Aeronautical Dictionary, which has been extracted from *All the World's Aircraft*, and edited by Mr. C. G. Grey. This dictionary, although not professing to be absolutely complete, contains most of the special words in common use by those concerned with aircraft, including a number of slang expressions which will be admitted into the English language with considerable reluctance. A dictionary is certainly necessary to explain some of these. Besides the dictionary the book contains a glossary of French and English technical terms used in the aviation industry, and also gives four large-scale sketches of typical pusher and tractor biplanes on which the various parts are named. Altogether the little book seems well worth its price, which is 1*s.* 6*d.*

EXHIBITS AT THE ROYAL AGRICULTURAL SOCIETY'S SHOW AT CARDIFF.

(*For Description, see Page* 836.)

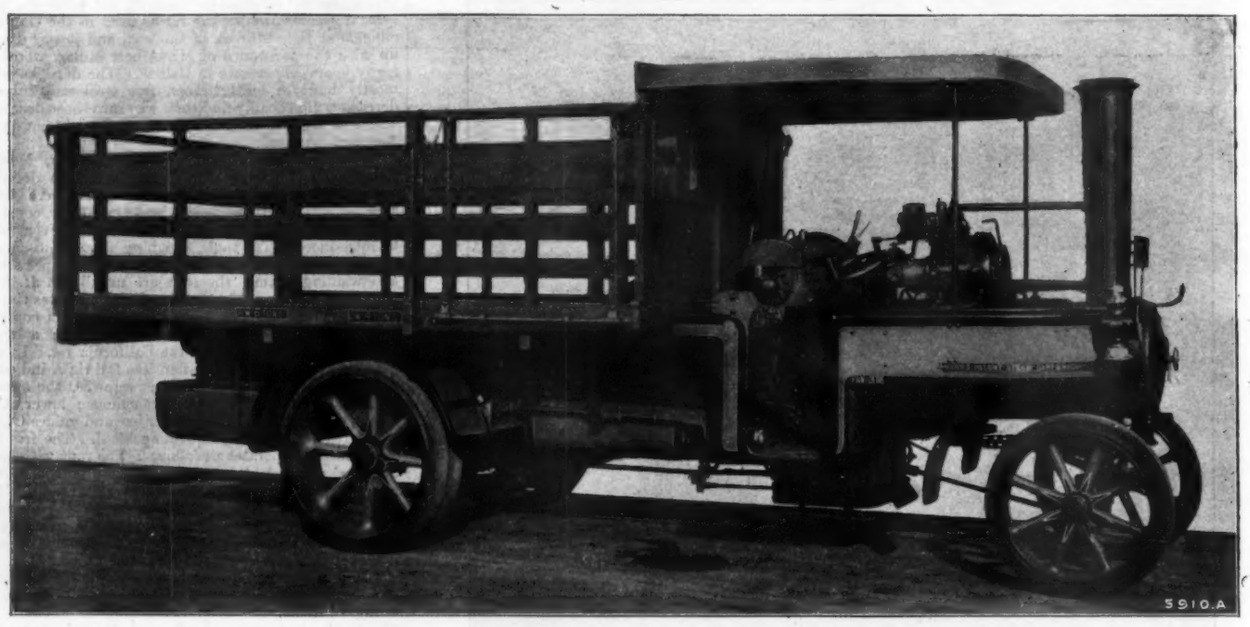


FIG. 1. 3-TON STEAM WAGON; MANN'S PATENT STEAM CART AND WAGON COMPANY, LIMITED, LEEDS.

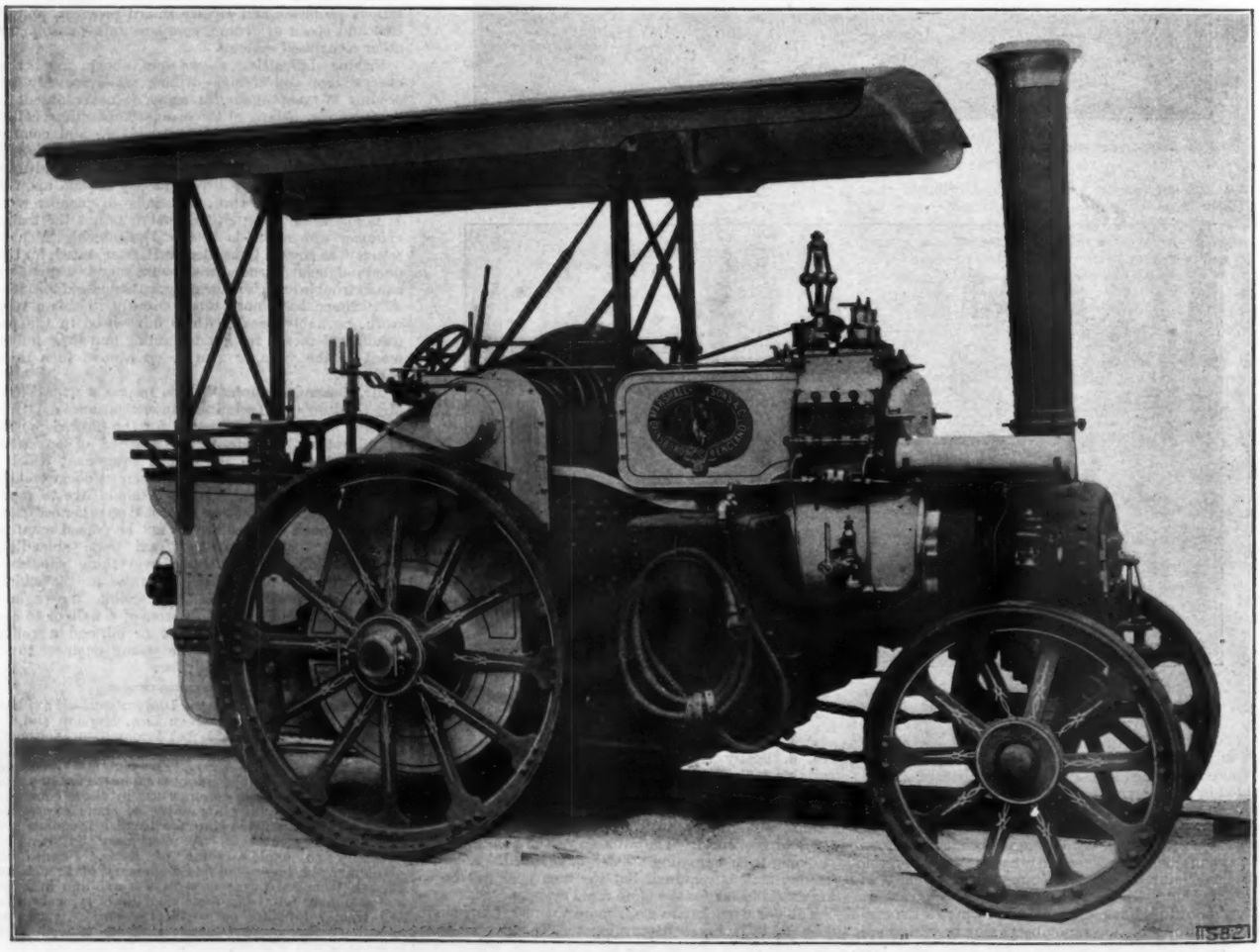


FIG. 2. TRACTION ENGINE WITH FEED-WATER HEATER; MESSRS. MARSHALL, SONS AND CO., LIMITED, GAINSBOROUGH.

EXHIBITS AT THE ROYAL AGRICULTURAL SOCIETY'S SHOW AT CARDIFF.

(*For Description, see Page* 836.)

FIG. 3. STEAM-DRIVEN AGRICULTURAL TRACTOR; MANN'S PATENT STEAM CART AND WAGON COMPANY, LIMITED, LEEDS.

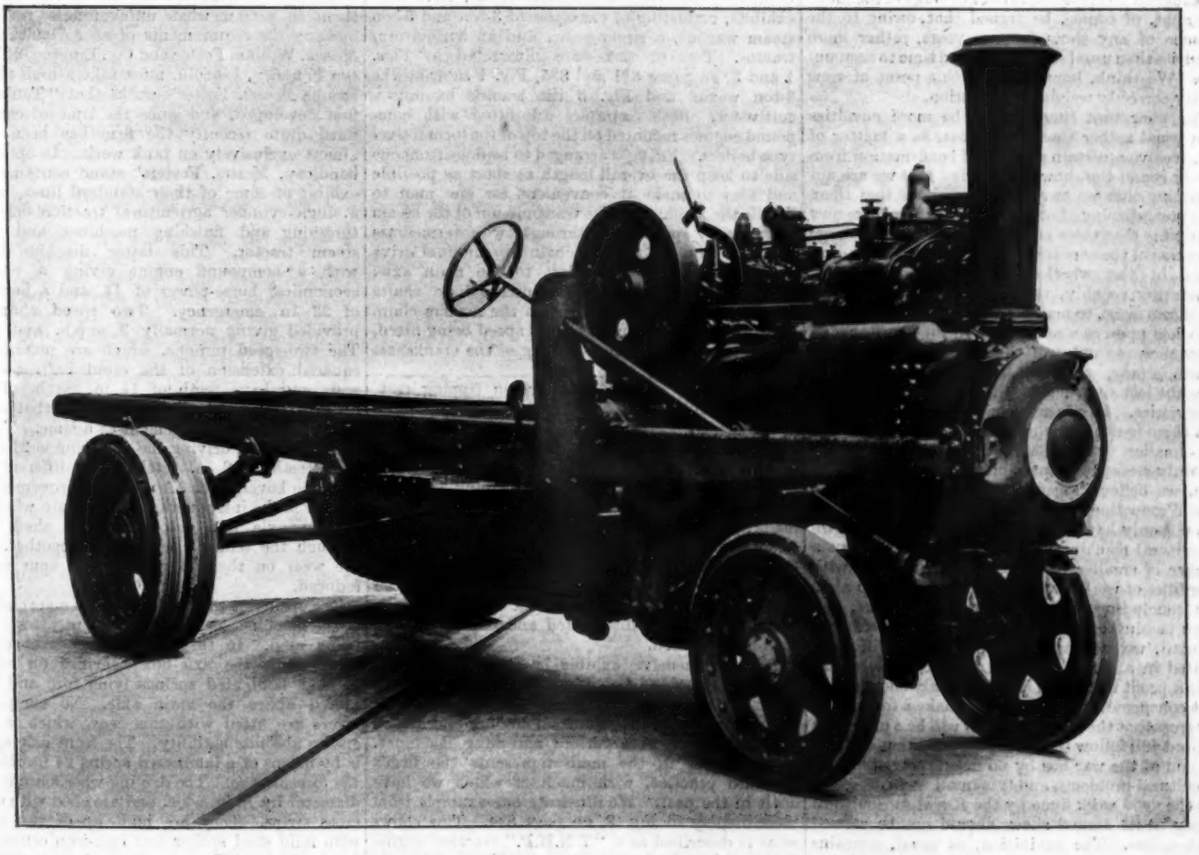


FIG. 4. 5-TON STEAM WAGON; MESSRS. ROBEY AND CO., LIMITED, LINCOLN.

THE ROYAL AGRICULTURAL SOCIETY'S SHOW AT CARDIFF.

AFTER an interval of two years the Royal Agricultural Society resumed its annual exhibitions on the 24th inst., when the seventy-eighth show was opened at Cardiff. Apart from the last two years, only once since 1839 has the show failed to be held. The society managed to carry on its exhibitions during the early years of the war, but difficulties accumulated, and after the Manchester show of 1916, further attempts were postponed indefinitely. It was intended that a visit to Cardiff should follow that to Manchester, and the invitation from Cardiff was accepted nearly seven years ago. The present exhibition may accordingly be considered as the postponed 1917 exhibition. As illustrating the increasing difficulties of carrying on the show during the war, it may be noted that the implement and machinery exhibits fell to 2,341 at Manchester in 1916, as compared with figures of about 5,500 at Shrewsbury, Bristol and Doncaster in 1914, 1913 and 1912. The falling-off in implements and machinery owing to the war was more marked than that of live-stock, which, in view of the war service of the engineering firms of the country, is not difficult to understand.

The present exhibition at Cardiff is the third which has been held in the town. At the first, in 1872, 5,843 implements were entered, and at the second, in 1901, 4,070. The figure for the present show is 3,918. This compares favourably with the 4,070 of 1901, but it still falls a long way behind the 5,500 of the immediate pre-war years. As compared with the 2,341 of the Manchester show of 1916, it is, however, excellent, and shows to what extent manufacturers have been able to get back to their pre-war work. Although, however, they have managed to make a start, it is probable that few have been able to consider new developments, and that, for the most part, it has taken them all their time to get their standard manufactures started again. It is accordingly not surprising that there is no great display of novelties in the show. It might, of course, be argued that, owing to the absence of any show for two years, rather more novelties than usual should have had time to accumulate. We think, however, that this point of view hardly correctly weighs the situation.

The view that there should be more novelties than usual rather than fewer does, as a matter of fact, receive a certain amount of confirmation from a walk round the show. In saying this we are not forgetting that we have said just above that there is no great display of novelties. What we have now in mind is that there is on view a remarkably large collection of the smaller type of agricultural tractor, either of the wheeled or endless track type. Estimating roughly, these are shown by at least two dozen firms, to many of whom this product may be looked upon as a new line. In the sense that so many new examples of this type of machine are shown, it may, we think, be said that the interval since the last show has resulted in an accumulation of novelties. In general, however, it must be said that there is not much new material on the stands. The smaller type of agricultural tractor, which certainly seems to be making a place for itself, has been, we believe, encouraged a good deal by the Food Production Department during the war, so that not only have some of the old and well-known agricultural machinery builders taken it up, but a number of smaller firms, or firms concerned with other lines of work have been led to take it up also.

In concluding these introductory remarks, and before passing on to consider some of the exhibits in detail, we may say that the first Cardiff show resulted in a deficit of 602*l.*, but that the second made a profit of 1,998*l.*, being the only show out of eight concurrently which did not make a loss. One may trust that the "Peace" show will be a profitable one, and will follow the example set by that of 1901. The end of the war has by no means solved all our agricultural problems, and it is in all ways desirable that the good work done by the Royal Agricultural Society in its annual shows should not be carried on at a loss. The exhibition, as usual, contains much to attract the general public and, in addition to the stock, poultry and machinery sections, contains displays dealing with flax production in Great Britain, a forestry exhibition, containing among other items one of the original oak purlins from Westminster Hall, a horticultural display, and a timbering competition for miners. Special arrangements are also made for officers and men of the Overseas Forces, who were engaged in agriculture in the Dominions, to visit the show.

Turning now to a description of some of the exhibits, we may refer in the first instance to that of Messrs. Ruston and Hornsby, Limited, of Lincoln, as it is near the main gate and is of an extensive nature. Messrs. Ruston, in common with many of the larger makers, exhibit no novelties, and their display is made up of examples of their well-known traction engines, tractors, portable engines, threshing machines, &c. Both single-cylinder and compound traction engines are shown. The compound engine is arranged so that steam at boiler pressure may be admitted to both cylinders for starting on load or climbing. The combined exhibit of the firms now forming Ruston and Hornsby make a very fine show.

Messrs. Aveling and Porter, of Rochester, who occupy a neighbouring stand, also confine themselves to standard material, showing a steam roller, a traction engine and a steam tractor. All the machines are fitted with compound engines, the roller working at 200 lb. per square inch, and the other two machines at 180 lb.; while they are all fitted with two-speed gear. Messrs. Richard Garrett and Sons, Limited, of Leiston, show a traction engine, steam wagons, a threshing machine, &c., from their standard lines of manufacture. The steam wagons are fitted with superheaters consisting of nests of steel tubes in cast steel headers, and so placed in a special chamber that they are clear of the boiler tubes and do not interfere with cleaning. The engines are fitted with balanced piston valves. The makers claim that their employment of superheating and piston valves results in an increased fuel economy of 25 per cent.

Messrs. Mann's Patent Steam Cart and Wagon Company, Limited, of Hunslet, Leeds, have four exhibits, consisting of examples of 3-ton and 5-ton steam wagons, a tipping cart and an agricultural tractor. Two of these are illustrated in Figs. 1 and 3, on pages 834 and 835, Fig. 1 showing the 3-ton wagon and Fig. 3 the tractor hauling a cultivator. Both examples are fitted with compound engines mounted on the top of the locomotive-type boilers. Firing is arranged to be done from one side to keep the overall length as short as possible and also to make it convenient for one man to handle the machine. The transmission of the steam wagon is by spur wheels through two intermediate shafts, with a roller pitch chain for the final drive from the third motion shaft to the main axle. The sliding gear is on the intermediate shafts instead of the crankshaft, which the makers claim allows of wider teeth and a third speed being fitted, in addition to avoiding overhang of the crankshaft bearing.

In the case of the steam-driven tipping cart, which we do not illustrate, the shorter body permits of a shorter wheel base, and the machine is accordingly driven throughout by spur gearing, thus doing away with the chain. The agricultural tractor is intended for direct ploughing or cultivating, as shown in Fig. 3. It is capable of hauling loads up to 6 tons on the road. It may also be used for driving threshing or other machinery by a belt from the flywheel. The road wheels have wide treads, and the total width is 4 ft. 8 in. As the front wheels come inside the track of those behind, the weight is well distributed and damage to the road is minimised.

A comprehensive exhibit is made by Messrs. Marshall, Sons and Co., Limited, of Gainsborough, consisting of examples of their traction engines and tractors, portable steam and oil engines and a road roller, together with various threshing machines. The material in the main represents the firm's standard practice, with much of which we have dealt in the past. We illustrate one example from their display in Fig. 2, on page 834. This shows what is described as a "7 N.H.P." traction engine fitted with a feed water heater. The machine is of the type which is largely used for driving threshing machines and other farm machinery, as well as for ordinary haulage work. The engine is spring-mounted, a laminated spring being placed below the smoke-box for the front axle; while at the rear a laminated spring is placed transversely below the main axle and connected to the frame by means of equalising gears.

The engine is mounted above the boiler, which is of the locomotive type working at 150 lb. pressure. The fire-box is of Marshall's special, and now well-known, form in which all girder roof stays are absent and their place taken by an arrangement of corrugations of the crown-plate, which we have already illustrated in ENGINEERING. The corrugations spring from each corner of the fire-box and intersect at the crown. The arrangement gives increased heating surface and reduces weight, while cleaning is much facilitated. The feed-water heater consists of a cylindrical casing fitted with a series of tubes and mounted on the forefront of the boiler. The feed water flows through the tubes and the exhaust steam surrounds them. The power transmission gearing embodies a four-pinion differential, whereby excessive wear and tear on the driving pinions is reduced and undue strain on the driving axle avoided. Chain-transmission steering gear, operated from a worm wheel, is employed and a brake is fitted to the back axle. A winding drum with 50 yards of steel wire rope is included in the equipment. The engine can haul about 36 tons gross weight, at its slowest speed, on good macadam roads.

Ploughing engines, road locomotives, steam tractors, &c., are shown by Messrs. John Fowler and Co. (Leeds), Limited, of Leeds. These, again, are of standard types. The ploughing engine is a very fine machine, and is, of course, built for cable ploughing. It carries 450 yards of cable on its winding drum. The tractor known as the "Tiger" is, we believe, a comparatively new product of Messrs. Fowler. It is fitted with a compound engine, which can be worked as a double-cylinder simple engine when starting.

Among the firms whose war service has placed them in a somewhat unfavourable position for meeting the requirements of an agricultural show, Messrs. William Foster and Co., Limited, of Wellington Foundry, Lincoln, must take a high place. It was at Messrs. Foster's works that "Tanks" were first developed, and since the time of early work until quite recently the firm has been engaged almost exclusively on tank work. In spite of this handicap, Messrs. Fosters' stand contains a good exhibit of some of their standard lines, including a single-cylinder agricultural traction engine, two threshing and finishing machines and a 5-ton steam tractor. This latter machine is fitted with a compound engine giving a continuous economical horse-power of 14, and a horse-power of 22 in emergency. Two speed changes are provided giving normally 3 m.p.h. and 6 m.p.h. The two-speed pinions, which are mounted on a squared extension of the crankshaft, are 1¾ in. wide and have teeth of 1¼ in. pitch. They are operated by two levers so arranged that only one pinion can be in engagement at a time. The intermediate pinion driving the spur ring is 2¾ in. wide, with teeth of 2 in. pitch. The differential gear is of the bevel type. A recent improvement in the tractor is the introduction of a feature whereby the bottom axle and second motion shaft passing through the tender rise and fall together, so that the wear on the top pinions and spur wheels is reduced.

The springing of the rear axle is a special feature of the machine, Messrs. Foster's outside spring gear being used. In this arrangement the support is direct from the axle-box bearings on each side through laminated springs lying fore and aft and placed above the main axle. No compensating levers are fitted with this gear, which is said to ensure absolute stability. The front axle springing is by means of a laminated spring 24 in. long below the forecarriage. The driving wheels are 5 ft. 2 in. diameter by 12 in. wide, and are shod with diagonal cross strips. They are built up of two tee-rings with mild steel spokes and cast-iron centres. The front wheels of the same type of construction, are 3 ft. 4 in. diameter by 5 in. wide.

Quite a varied display is made by Messrs. Robey and Co., Limited, of Lincoln. It includes a 5-ton steam wagon, a compound steam tractor, a portable engine, a cylinder fitted with drop-valve reversing gear suitable for winding engines, together with examples of crude oil engines. The steam wagon, which may perhaps be considered the principal exhibit, we illustrate in Fig. 4, on page 835. This figure gives an excellent idea of the construction of the wagon, which the makers claim to be the lightest overtype wagon on the market. With a platform body fitted the front axle weight is 3 tons 7 cwt., and the back axle weight 7 tons 12 cwt. Considerable attention has been paid to ease of control. As will be clear from the figure the position of the driver is such that his view of the road both in the front and at the sides is very clear. Further, in addition to foot throttle control, the engine has a foot brake fitted so that in emergency the drivers hands are both free for controlling the steering wheel, and he can sit to his work in comfort. All levers are placed within easy reach so that one man has no difficulty in driving and controlling the wagon. The boiler is of the locomotive type, but no stays are used. As will be seen, the wagon is fitted with rubber tyres.

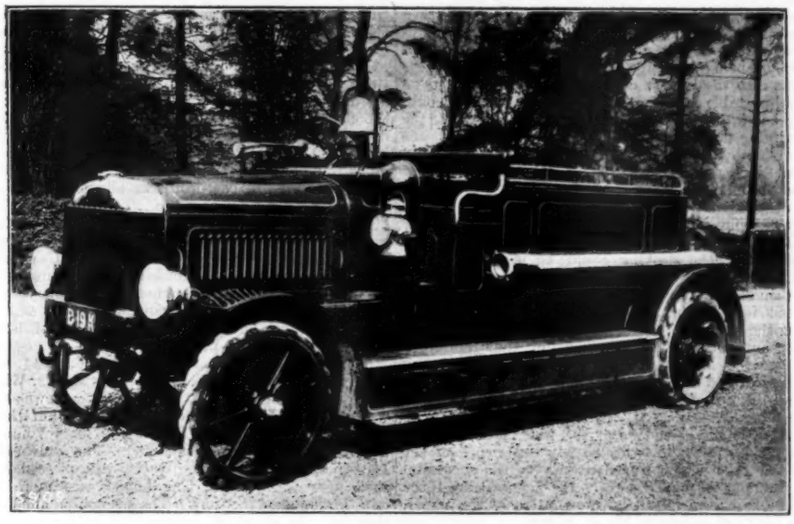


FIG. 7. MOTOR FIRE ENGINE; MESSRS. LEYLAND MOTORS, LTD., LEYLAND, LANCS.

From among the various endless track creepers and similar special types of tractor we have selected for illustration this week examples by Messrs. Martin's Cultivator Company, Limited, of Stamford, and Messrs. Clayton and Shuttleworth, Limited, of Lincoln. These are shown in Figs. 5 and 6, on page 842. There is no doubt but that tractors of this class have a valuable field of work, and that they are able to be employed in cases in which either a wheeled tractor could not operate at all, or could only do so to the damage of the land. Messrs. Martin's machine is primarily a motor plough, and is so illustrated in our figure. The appliance, however, is so constructed that the plough frame can be easily detached from the chasses and replaced by a wheeled under-carriage. The tractor may then be employed for working cultivators, mowers, &c., or may, by means of a pulley, which can be attached, be used for driving fixed machinery.

The tractor is fitted with a four-cylinder four-cycle engine, 3¾ in. bore, and 5 in. stroke, arranged to start on petrol and run on paraffin. Power is transmitted from the engine through a "Ferodo" faced cone clutch to an enclosed gear-box, which gives one forward and one reverse normal speed of 3 miles an hour. The main cross-shaft extends through the side of the gear-box and carries two sprocket wheels, which drive the endless track creepers. The sprockets are driven through dog clutches, and a single lever operates these clutches and also the engine clutch. The track creepers may be independently adjusted and can act as land and furrow wheels respectively, and also regulate the depth of ploughing. Steering is by hand-wheel, worm and sector. The machine as shown in Fig. 5 is the standard form, fitted with a three-furrow plough, but a frame carrying two-furrow digging ploughs can be supplied. A recent improvement in this machine is the fitting of an automatic lift for the plough. When the machine is working, the ploughs may be lifted at the end of a furrow or elsewhere by touching a foot-pedal, and may be lowered again in the same way.

The Clayton and Shuttleworth endless track tractor, or "caterpillar" tractor, as they call it, is a new product for the firm, and was built to meet the urgent demands of the Food Production Department during the latter stages of the war. It has been used in various parts of the country under the auspices of the department. The general appearance of the machine is shown in our illustration, Fig. 6, page 842. It is fitted with a 35-h.p. Dorman four-cylinder engine, arranged to start on petrol and run on paraffin, only one carburettor being used. The fuel tanks to be seen on the top of the machine; each has a short-end section to carry petrol. The consumption of paraffin is from 2 gallons to 3 gallons an acre. The engine drives through the usual clutch to a gear-box fixed at the back of the machine, and to which the driver's seat can be seen to be attached in the figure. The drive to the track is from the gear-box through a fore-and-aft shaft which carries a bevel pinion driving a bevel wheel on a cross-shaft. The cross shaft carries two dog clutches, which drive the roller pinions gearing with the endless track sprockets. By means of the clutches either or both of the endless tracks may be operated. The end of the roller pinion driving the sprocket can be seen in the figure. Connected with each pinion there is a brake drum acted on by a band brake, and when steering, one pinion being driven, the other is locked with the brake, so that one of the endless tracks may be completely prevented from travelling while the other swings the machine around. The endless track is built up of pressed steel plates with embossed "V" treads, and is carried on guide pulleys as shown. The endless track chain is tightened up by means of square thread screws which press against the large forward guide pulleys. These screws take the weight while the journal brackets, which have slotted holes, are adjusted. Lubrication of the chains is by drip from the oil reservoir shown behind the engine casing, while the guide pulleys have screw-down grease cups.

The last of our illustrations dealing with the show this week, Fig. 7, on the present page, shows a motor fire-engine exhibited by Messrs. Leyland Motors (1914), Limited, of Leyland. Messrs. Leyland Motors are one of the firms which has been fortunate enough to be engaged on their own type of manufacture throughout the war period, they having delivered some 6,000 heavy motor vehicles to various war departments. The greater proportion, over 5,000, were delivered to the Royal Air Force, and the remainder included many special vehicles, such as 570 portable workshops, many dentists' vans, special aeroplane carriers, searchlight carriers, &c. Their Cardiff exhibit consists of a motor fire-engine, steam and motor wagons, and a motor char-a-banc. The fire-engine is shown in our figure. It is fitted with a four-cylinder 55-h.p. engine, and is able to pump 380 gallons of water a minute at 160 lb. pressure and 580 gallons at 80 lb. The same engine is used for travelling and driving the pump. For travelling the gear-box gives four speeds and reverse, while an independent gear is thrown in for the pump drive. A Rees Roturbo pump is used and an independent reciprocating pump is fitted for priming. The engine, as exhibited at the show, carries an extending fire escape on "V" brackets at the back and resting on a frame built above the wind screen. This is not shown in our illustration.

An interesting and simple adapter for a Ford chassis is shown by Messrs. Morris, Russell and Co., Limited, of 163-165, Great Portland-street, London, W. 1. This consists of what is called a tractor unit, which is a simple frame designed to fit on the back of a Ford chassis when the wheels have been removed. The Ford wheels are replaced by roller pinions which work on internal teeth on the wheels which form part of the adapter. These wheels are of the ordinary tractor type with spuds, and the fitting of them, together with the roller pinions and frame, converts the Ford chassis into a type of agricultural tractor. Steering is carried out from the front wheels in the ordinary way and apparently it is usual to leave the rubber tyres on these wheels. The arrangement is obviously very simple and inexpensive, but not having seen it at work one would be interested to see the efficiency of the control on rough land. Messrs. Morris and Russell quoted Mr. S. F. Edge that it is "equal in ploughing output to a Ford farm tractor." It should be said that the conversion of the Ford chassis includes the fitting of a new radiator, fan and water pump, in addition to the mounting of the adapter.

Among the smaller agricultural exhibits we noted a neat potato sorter shown by Henry Wallworth, of Tytherington Old Hall, near Macclesfield. This consists of a series of superimposed riddles, or sieves, of different meshes. The riddles are sloped, and deliver each to a different sack. The whole arrangement is mounted so that it can be oscillated, and as the mixed potatoes are fed to the top they travel through or off the various riddles, depending on their size, and are sorted out. The appliance is operated by hand. As will be clear, it is a simple one, but has been worked out in a neat and mechanical way. Another exhibit which we should briefly mention is shown by Messrs. George Cradock and Co., Limited, of Wakefield. This firm has a good display of its well-known wire ropes, examples being shown for steam ploughs, traction engines, mining, &c. The exhibit to which we wish to call attention, however, is a locked coil rope for use in wet shafts, on aerial ropeways, and in other situations in which there is danger of internal corrosion. The special rope shown has each wire of which it is built up coated with a layer of protective metal—the metal used is not stated—which not only prevents corrosion, but also ensures perfect locking. To conclude our notice this week we may refer to a good display of mining pumps and main and tail haulage gears shown by the Uakside Engineering Company, Limited, of Newport, Mon. This display, although not perhaps of agricultural is distinctly of engineering interest. The largest gear shown has two 5 ft. drums and is driven by a 500-h.p. motor. The drum speed is 28 r.p.m., they being driven through double-helical main gear and a machine-cut train to the pinion. The makers' form of flexible coupling is fitted between the motor and pinion shaft. It consists of two clutch faces, with interlocking teeth between which blocks of rubber with hardwood backing are fitted.

(*To be continued.*)

THE INSTITUTION OF GAS ENGINEERS.

(*Concluded from page* 802.)

MR. BROADBERRY, in opening his paper on "The Application of Reinforced Concrete to Purifier Construction," stated that the desire to construct purifiers in reinforced concrete had been present in his mind for a considerable number of years, but that it was only recently that the opportunity came for him to realise it at the works of the Tottenham District Light, Heat and Power Company, of which he is the chief engineer. It came with the building of an entire new section of the works, which was first contemplated in 1910, but not started until 1914. The purifiers for this had to be designed for dealing with a make of gas of 5,000,000 cub. ft. per day. The principal risks in connection with the proposal appeared to be: (*a*) The possibility of minute fractures due to expansion and contraction from changes of temperature, and to varying pressures of gas in the boxes themselves; (*b*) the imperfect joints between the concrete where the work had to be left (possibly sometimes for days) between the time when one stage of the work had to be stopped and the next stage commenced; and (*c*) the possible porosity of the concrete itself.

In consideration of the first-mentioned risk, it was decided to subdivide the five purifiers, working them in three boxes (Fig. 1, page 839), two being arranged as twin purifiers, and the third, separate, to be used as a catch purifier. To overcome the second objection (imperfect jointing) it was proposed to make the casting continuous. This, however, was subsequently found to be impossible, but special care was taken to secure the best possible cohesion of the work, particularly at the jointing. In order to guard against the possible porosity the interiors were all treated with three washes of "Ironite." This rendered the concrete impermeable, except, in a very few slight cases at the joints of the work, which would be treated on the inside with a mixture of hot tar and pitch.

The design of the work naturally necessitated, first, a study of stresses, particularly those that did not enter into calculations for reinforced concrete constructions of the ordinary kind. The most important of these were those due to the pressure of the gas. It was assumed that 48 in. would be the maximum, which was equal to a pressure of 1¾ lb. per square inch. At this pressure the floor load was increased by 266 tons in each purifier, equal to 1 ton per square yard. The interior stanchions which support the decking round the four cover openings of the purifier when not at work had to be designed to act as ties between the floor and the gangways when the roof was subjected to the upward pressure (Fig. 3). The deck surrounding the outside of the cover openings had to serve as a horizontal girder to resist the outward pressure on the sides at the top, and provision had also to be made to secure the sides firmly at their junction with the floor (Fig. 4). The main beams had a span of 21 ft. 8½ in., with a total depth of 33 in. (Fig. 5). The secondary beams had a span of 14 ft. 3½ in., were 21 in. deep, and spaced 5 ft. 5 in. centres (Fig. 6). The floor slab was 5 in. thick (Fig. 7). The stanchions (Fig. 8) were 15 in. square for the interior, and 13 in. for the exterior. They were strongly reinforced and had to carry a deadweight load of 54 tons and 36 tons respectively. They rested on mass concrete foundations, 5 ft. square, carried down to firm ballast, and were brought to a uniform level 8 ft. below ground.

As to the covers, the author stated that as it had not been thought that reinforced concrete was applicable for this purpose, only steel was considered; but the difficulties of the made-up material did not appear to be insurmountable. The covers, shown in Fig. 2, had a steel channel curb, which was welded at the joints to ensure their being gastight. The fastenings consisted of a special type of eccentric (Fig. 9) in which the fixed pins were held by cast-iron blocks bolted to the channels between the flanges. The hooks engaged with steel lugs (Fig. 10) which were designed so that they could be put in place and concreted in without interfering very much with the shuttering. The eccentrics would give a good tightening grip at widely varying angles, and the adjusting screw would provide in each case for giving the eccentric its maximum movement.

The method for raising the covers when the purifying material had to be renewed was a simple form of hydraulic jack on a carriage running on a light railway track (Fig. 1). It was suggested by Mr. A. A. Johnston, of Brentford.

After describing the attachment of the inlet and outlet pipes, the author referred to the bottom discharge doors (Fig. 12) for the spent oxide. It was desirable to ensure a straight and unimpeded fall for the spent oxide; the lid was therefore designed to be operated by a screw to tighten it against the rubber joint. The whole arrangement was fitted on a running carriage (Fig. 12) so as to be moved easily quite clear of the opening. The grids for carrying the oxide were of novel design, for which the author expressed his indebtedness again to Mr. Johnston. They were shown in Fig. 13, and were easily made and repaired. In Fig. 1 the grids and bearers were shown as they would now be arranged in the light of experience. There were only two layers of oxide in each purifier. In Fig. 11 (a section of an inlet pipe) it would be noticed that there were portholes below the bottom layer, while the open end of the pipe was above the top layer. The outlet pipe was taken from between the two layers; thus ensuring the slowest possible travel of the gas through the purifying material, and the reduction of back pressure to a minimum.

An account followed of the testing of the purifiers with water and of the method of testing the decks. In the latter, after the covers had been put on, a dam of clay, about 4 in. high, was made across the end of each gangway, and the whole enclosed area of the concrete was covered with water about 3 in. deep. The exhausters were then set to work compressing air into the purifiers until a pressure of 36 in. was attained. The presence of leaks would thus be indicated by air bubbles coming up through the water. The result was a negative one. The absence of leaks was inferred from the absence of bubbles.

Owing to war conditions it was decided not to adopt an elaborate scheme for handling the oxide. As shown in Fig. 2 it consisted of an elevator which discharged the oxide into a concrete hopper on the top deck, from which barrows were filled by gravitation, and were then wheeled on movable runaways across the openings to the place where it was to be deposited. The spent oxide, on being discharged, dropped through discharge spouts into the hopper of a disintegrator mounted on a semi-portable carriage. The pulverised material could then be directly wheeled and distributed about the revivifying floor. The sequence of the purifiers was controlled by a Weck valve, indicated in Fig. 1.

The success of the Tottenham set of purifiers justified the adoption of the same principle to some new purifiers for cyanide extraction at the Ponders End works. They are shown in Fig. 14, and are of much simpler construction, first because they are much smaller, and consequently the decking could be more extensive, and the covers (which for cyanide were made of cast-iron) smaller in proportion. Reinforced concrete was utilised for the supports of the runaway beam for lifting the covers.

The author remarked in conclusion that reinforced concrete for large purifiers was undoubtedly very economical and could be made more so if standardised in multiples of even feet dimensions, so as to allow of the use of standard shuttering. Care had, however, to be taken in the execution of the work, which should be entrusted only to firms having experience of the essential care which was necessary to the successful carrying out of the designs. He acknowledged the help he had received in the preparation of the paper, from his chief assistant, Mr. J. Fisher.

In the discussion which followed, after the president had expressed the thanks of the Institution for the paper, Mr. Thomas Goulden (London) congratulated Mr. Broadberry on the courage he had shown in constructing his purifiers of reinforced concrete. Mr. Goulden's company (the Gas Light and Coke Company) had had occasion during the war to get out some purifiers, and had been driven to use concrete, owing to the lack of iron and steel, but apart from that consideration he certainly would have used concrete. He had used it for coke bunkers and was now employing it for coal bunkers. The material was cheaper than iron or steel.

Mr. W. Newton Booth (Woolwich Arsenal) mentioned that he put in some concrete purifiers quite recently, and had been very well satisfied with the result. The boxes consisted of a range of five purifiers, 29 ft. by 26 ft. inside, and about 5 ft. 9 in. deep, resting on the ground, which, being damp clay, would not give much heat through the bottom. When they began to test the boxes they found the same trouble as Mr. Broadberry had—the places where the casting had been finished off at night and was proceeded with next morning were certainly weak. The method he had adopted for getting over that was to drill a small number of holes into the porous portion, and to pump in thin grout under pressure. It had answered admirably. Four of the boxes had been treated with two coats of "Ironite" and no leakage had occurred after that treatment. The fifth box, as an experiment, had been treated with a solution of water glass (four coats applied like whitewash) and that had also proved quite successful.

Mr. R. Bruce Anderson (London) said about twenty years ago he had occasion to erect some purifiers, and on going into the cost found that he could make them more cheaply of iron than he could of concrete; but he had used concrete for the bottom and iron for the sides. For a comparatively small job, when the expense of moulds, &c., was taken into account, a concrete bottom and cast-iron sides was less costly. Another objection to using concrete for the sides was that whereas iron would only be about 1 in. in thickness, the concrete would be about 7 in., and that took off a foot from the width of the inside dimension of the purifier. He suggested that the author might have used his gas inlet and outlet pipes as discharging doors for his oxide.

Mr. H. Simmonds (Bury) asked whether any tests had been made as to the relative efficiencies of upward and downward purification; and Mr. J. H. Brearley (Longwood) inquired as to the comparative costs of the two methods of construction. Mr. J. Fisher (Tottenham) desired to thank Mr. Broadberry for his generous recognition of his (Mr. Fisher's) work at Tottenham.

Mr. Broadberry, in replying to the discussion, regretted to say that no tests had been made. No particular difference in the condition of the oxide in the top and bottom layers had been observed, but he would certainly take some tests in the future to ascertain whether the top or the bottom layer was more active. He did not think, however, that very much difference would be found, from the appearance of the oxide itself. He thought probably the trouble encountered by Mr. Booth when working the up and down system had been from the rapid speed at which he had to pass the gas through the purifiers. He regarded the splitting of the streams as being particularly advantageous in giving a slow travel of the gas through the purifying mass. It left a longer time for the chemical reaction to take place. As to the question of cost, it had been arranged to put in a set of purifiers in concrete at the Ponders End works, for gas purification. They would be five in number, each measuring 38 ft. by 20 ft. by 6 ft. deep, and the contract price for the concrete portion of the body amounted to 3,320*l.*, or 2*s.* 3½*d.* per cubic foot of purifier space. If executed in metal the cost would be 6,420*l.*, or about twice as much. Whether taken at pre-war prices or present prices, the cost of cast-iron was about 100 per cent. more than reinforced concrete.

The concluding paper, which was given in abstract, was by Mr. H. Townsend, M.Inst.C.E., of Wakefield, on "Some War Experiences of British Gas Undertakings." It contained accounts of the damage done at various gas works throughout the country during the war through bombardment, air raids, &c., and was illustrated by an interesting series of lantern slides prepared from photographs.

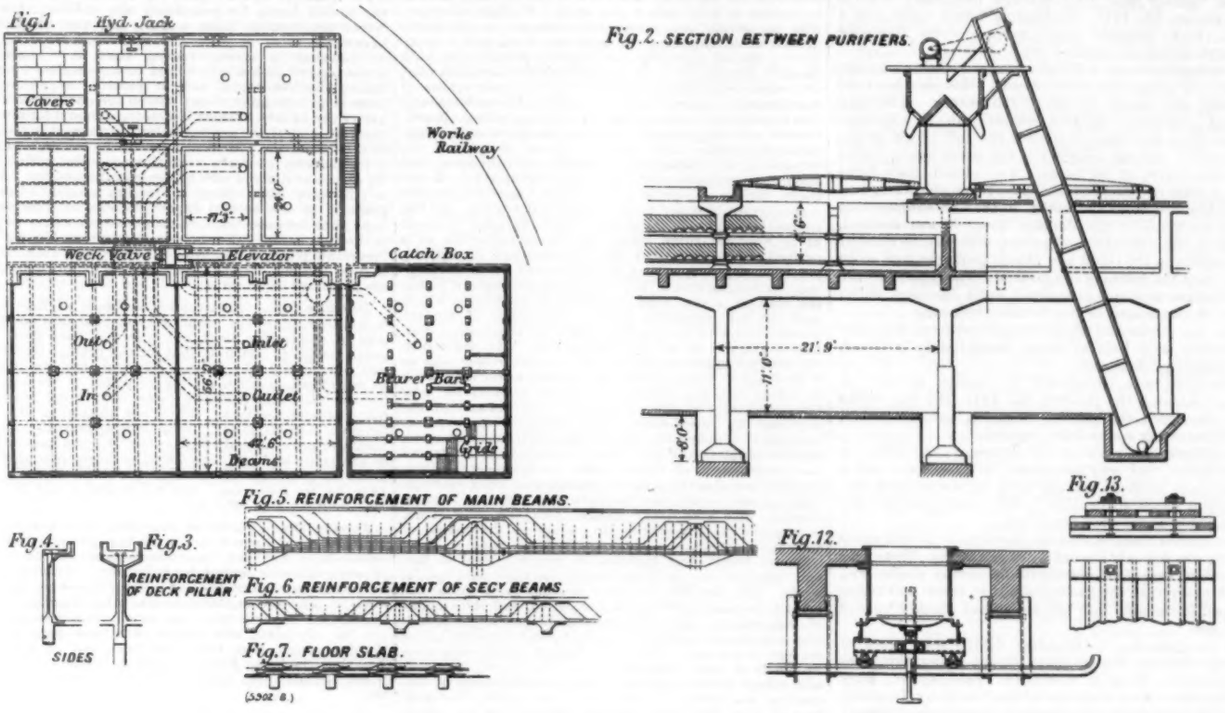
The first occurred on December 16, 1914, when enemy battleships attacked the Hartlepools, Whitby and Scarborough. At the two latter towns there was considerable loss of life and damage, but the gas works escaped. At the Hartlepools several hundred people were killed and maimed. The crown of a 140-ft. diameter gasholder there was pierced by a shell near the centre. The holder was more than two-thirds full at the time. The gas ignited and flames shot up. In about 15 minutes the holder was down on the rest-stones, but the flames continued under the crown for over two hours before being finally extinguished. Three of the roof trusses were badly damaged, and 285 holes pierced the sides and crown from within by the fragments from the bursting shell. The smaller holder was also struck, and damage was done to the retort houses. At the No. 2 gas works, a three-lift column-guided holder, 150 ft. diameter, was struck by three shells, the first striking the dip of the outer lift; the second hit the top curb angle and then burst, sending the curb of the holder inwards for a whole bay, and ripping the top sheets open very near to the crown plate. The third shell struck one of the standards, carrying part of it away.

A description was given of how the repairs were carried out. Although the damage had been so extensive, in less than 60 hours after the bombardment the gas supply was resumed. On three occasions Zeppelins had dropped bombs on the town, and in the last raid, on March 8, 1918, several were dropped near the gas works but did very little damage.

A record of the experience of the Gas Light and Coke Company followed. With the exception of one raid on October 19, 1917, all the Zeppelin raids occurred between May 31, 1915, and June 15, 1917, during which period the company were very fortunate, no main larger than 12 in. being damaged. Perhaps the bomb resulting in the most troublesome repair was that which fell in Wellington-street, by the Lyceum Theatre, on October 13, 1915, which involved the bagging off of four mains before the escaping gas, which had fired, could be stopped. There were 31 aeroplane raids, of which warning was received, and damage to mains and services was done on 16 occasions. The most remarkable damage was during the night of September 4, 1917, when an aerial torpedo fell on the Embankment by Cleopatra's Needle, on the pipe subway running from Westminster Bridge to the Mansion House. A large section of the crown of the subway was broken down, and a 30-in. pipe in a low-pressure main was completely shattered. The repair was

THE APPLICATION OF REINFORCED CONCRETE TO PURIFIER CONSTRUCTION.

MR. A. E. BROADBERRY, M. INST. C.E., CHIEF ENGINEER TO THE TOTTENHAM DISTRICT LIGHT, HEAT, AND POWER COMPANY.



completed by 1.30 p.m. the following day. On October 1, 1917, an anti-aircraft shell, which failed to explode, pierced one of three 21-in. mains lying under the wooden decking of the Grosvenor-road railway bridge. Subsequently the gas was exploded by a passing train—the wooden decking being blown up. The train was fortunately untouched. The fire melted the lead from joints in all three mains, and could only be extinguished by water-logging the pipes with the aid of the fire brigade. One chief source of anxiety was mains in subways, of which there were 9 miles in the company's area. They contained mains from 48 in. downwards. In order to minimise the danger, only as many valves were left open as were necessary to maintain an adequate supply of gas to the consumers affected. Of the 40 valves it was found possible to close all except six. Men were stationed at the various sub-offices of the company during raids, and as many as 10 motors were in readiness to carry men and tools wherever damage was reported.

At Edinburgh, on April 3, 1916, a Zeppelin bomb was dropped on the Grassmarket, shattering a 5-in. main.

On April 25, 1916, Gorleston and Great Yarmouth were bombarded. A gasholder of 60,000 cub. ft. capacity was struck in two places in the crown, and the gas became ignited. The flame was extinguished by smothering it by building in with bricks and plastic clay. Another holder was also pierced by a portion of a shell, and about 120,000 cub. ft. of gas was lost. The hole was roughly stopped while a square of ½-in. plate was worked to suit the irregular condition of the sheet, and was bolted on. The retort-house chimney was brought down by a shell fragment and the heavy vibration. Other portions of the works were also damaged.

The chemical works explosion at Bradford on August 21, 1916, through which the Corporation gas works were extensively damaged, was next referred to. Unfortunately, 38 persons were killed and many injured. Both gasholders close by were well filled at the time. The three-lift holder had its crown torn open outwards, the roof trussing was seriously displaced, and most of the vertical channel stays were buckled. The single-lift holder crown also was torn, and the side sheets badly damaged. In both holders the guide-framing was not injured, but it was necessary to plumb and adjust it. The works buildings were damaged by flying fragments. The gas in the large holder did not fire at all; that in the smaller was ignited by flying fragments from the chemical works, after it had grounded. Owing largely to the delay in obtaining steel the repairs to the three-lift holder were not completed until the end of November, 1916; and the smaller holder was not available until the following May.

Considerable damage was done at Tynemouth on August 8, 1916; the whole of the gas company's showroom was wrecked, and a 4-in. main completely shattered.

At Retford, on the night of September 3-4, 1916, during a Zeppelin raid, two bombs fell in the gas works, one of them making about 300 holes in the largest gasholder. The second made a large hole in the side sheeting of No. 2 holder, the sheeting being blown up into, and twisting round the roof trussing of, the holder. Through the same bomb great damage was also done to a small holder. The gas immediately ignited in all three holders, the valve room caught fire, but was got under, and the holders eventually burned themselves out.

The damage done at the East Greenwich works of the South Metropolitan Gas Company through the Silvertown explosion on January 19, 1917, was next described. No. 2 gasholder, of 12,000,000 cub. ft. capacity, was completely wrecked, and No. 1 was damaged. The stock of gas in No. 2 holder at the time of the explosion was only 7,865,000 cub. ft., proving that the top lift was well within the guide columns. So far as working conditions were concerned, the holder, at the moment of the shock, was probably in the best position to resist any unusual strain, such as a gale of wind or drifting snow, provision for which had been foreseen, and duly provided against. The holder, however, had not been built to stand up against the shock of an explosion of a large quantity of T.N.T. occurring at a distance of 1½ miles as the crow flies. It must have been wrecked either by the pressure produced in the atmosphere by the explosion or by the vacuum immediately succeeding it. The blinding glare which was observed throughout the whole of London at 6.52 p.m. on that January evening was undoubtedly due to the burning in a few seconds of about 8,000,000 cub. ft. of gas contained in this holder. The South Metropolitan Gas Company's West Greenwich, Vauxhall, and Old Kent Road works

also sustained damage on various occasions. That at Vauxhall cost nearly 2,000*l.* to effect the necessary repairs.

At Southend, during the first raids, from Zeppelins, much damage was done through incendiary bombs. On August 12, 1917, the leading trunk main and a 10-in. high pressure main were severely damaged through an aerial torpedo.

The explosion at a T.N.T. works at Ashton-under-Lyne, on June 13, 1917, caused the death of 49 persons and injury to about 700 others. The two largest gasholders, each of 854,000 cub. ft. capacity, about 50 yards away, received the full shock of the explosion; the gas caught fire and when nearly burnt out, the valves of the holders were closed, they being then a mass of ruined materials. When the water had been removed from the tanks, so that an examination could be made of the damage done, it was decided, owing to the difficulties of getting material, to convert the holders to the Gadd and Mason principle, and so do away with the columns and girders. The repairs to the first holder were not completed until January, 1918; those of the second in the October following.

The gas works at Dukinfield suffered from the same explosion, both holders being immediately wrecked, and buildings damaged.

Ramsgate was threatened by enemy aircraft on 119 occasions. On October 31, 1917, the gas works were damaged, the purifier house, a two-lift holder, and three trunk mains being injured.

Brentford was visited on January 29, 1918. A retort-house roof was damaged; a 6-in. main and a 26-in. main broken; the gas from the latter took fire, causing a flame 40 ft. high. The means adopted for getting this under were described.

The author claimed that the particulars he had given proved conclusively the safety of gas works. Numerous gasholders had been destroyed by enemy shells, &c., but in every case the gas contained in them had either escaped harmlessly into the air or had quickly burned itself out.

In an appendix to the paper details were given of damage done to the property of gas undertakings at Scarborough, Whitby, Gorleston, Bridlington, Bury St. Edmunds, Hull, Commercial Gas Company (London), South Metropolitan Gas Company (distributing plant), Sunderland, York, Harwich, Lincoln, Margate, and Peterborough.

The concluding business of the meeting consisted in the election to honorary membership of the Institution of the respective presidents of the technical gas societies of France, America and Italy; the decision to leave the date and place of the next meeting in the hands of the council; and votes of thanks to the president, council, hon. secretary, secretary, research committees, scrutineers and auditors, and to the Institution of Civil Engineers for the use of their hall, and for the facilities extended in connection with the meeting.

THE LORD ROBERTS MEMORIAL FUND.—The Lord Roberts Memorial Committee paid out in wages during 1918 the sum of 44,199*l.* to disabled men. Over 60 per cent. of the men employed are one-armed cases. The men are trained in the use of tools and machinery and, what is far more important, provided with permanent employment in the workshops at good wages. Already 1,643 men have entered the workshops (of which there are 11 in different parts of the country). The committee are appealing for 500,000*l.*, to enable them to extend the work so as to take in some thousands more. The Organising Secretary, 120, Brompton-road, S.W. 3, will be pleased to hear from anyone who would like to help in this important work for the disabled men, by service or gift.

LAMP FOR PHOTOMICROGRAPHY.—Before the New York Section of the Society of Chemical Industry, Alexander Silverman, of the University of Pittsburgh, recently described a new lamp outfit for photomicrographic work, which is said to be very convenient for metallographers. The lamp is a ½-in. tube of colourless or blue glass, partly silvered, which is bent to a circle of 1½ in. external diameter. The single tungsten filament of the lamp can be run, for visual work, at 0·7 ampere and 9 volts for about 900 hours; or at 0·9 ampere and 13 volts for 150 hours for microscopic work; or at 1·02 amperes and 18 volts for 8½ hours. The last conditions are suitable for photographic work with exposures of 15 seconds on an average. The light is reflected conically from the circular source to the portion of the object under examination. The lampholder is ring-shaped; three iris-like fingers extend inward from the ring to clamp the holder to the objective; the lamp may also be attached to the tube of the microscope, and the objective raised or lowered inside the tube; the lamp is thus maintained at a constant distance from the object, and as the lamp surrounds the objective, reflected rays only pass into the microscope tube, and the eye is not strained. The illumination is said to give remarkable microscopic details. A special rheostat is provided for the current regulation, and the lamp may be connected with circuits of 110 volts or of 220 volts. The devices are patented.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The vitality of local industry, despite high prices of basic material and keen competition, is indicated in the proposals on foot to extend existing industries and introduce new ones. Sheffield Corporation is taking an exceptional interest in directing industrial development on approved lines, and a committee formed specially to consider possibilities puts forward among its chief suggestions the establishment of central engineering works for the construction of standardised cutlery material making, file-making, and other machinery on modern lines, pen-making, manufacture of hosiery, and lace-making machines and sewing-machine needles, and indicates there is ground for expansion in refractory material manufacture and surgical-instrument making. Cold rolled strip of the cheap variety is wanted in enormous quantities for the manufacture of many kinds of essential articles, and the committee suggest that inquiry might usefully be made as to Sheffield firms taking up its manufacture as a profitable side line, and that the industry of nippers, pincers and pliers-making should be well worth developing. A programme of this comprehensive nature points the way to a vast field of industrial enterprise which may extend somewhat beyond the reach of current possibilities, and it is certain that the suggestions contained will not be wholly disregarded. The position in the heavy engineering trades remains much the same as a week ago. Steady progress is being made with work in hand, but the number of orders booked for new business comprise only a fractional proportion of the inquiries in circulation, particularly from overseas markets. A policy of caution seems to influence buyers, due no doubt to the high cost of finished materials and the uncertainty of future price developments. Shipbuilders are absorbing large quantities of steel castings, forgings and tools, and business with the Far Eastern Markets and with Italy, Spain, Australia, and India, is improving. Practically the whole of the output of railway and tramway material is going away to meet contract needs, but business in crucible steel is flat, and there is very little movement in high-class special steels. The number of firms making such steels has greatly increased during the war period, and the amount of business on offer is scarcely sufficient to go round. The pressure on production in the lighter branches shows no sign of waning. Two of the largest engineering firms in Sheffield have extended their file-making sections, and others have introduced further installations of file-making machinery to cope with the healthy demand. For all tools like pliers, nippers, and pincers, the call is very active. Several firms are booked up until December. There is no change in prices of basic material, with the exception of steel billets, which have advanced 10*s.* per ton to the following level: Bessemer acid, 17*l.* 2*s.* 6*d.*; Siemens acid, 17*l.* 12*s.* 6*d.*; hard basic, 15*l.* 2*s.* 6*d.*; soft basic, 14*l.* 12*s.* 6*d.*

South Yorkshire Coal Trade.—The output at the pits has only just regained its equilibrium after the Whitsuntide set down, and pressure on supplies is great, leaving only a very small tonnage for open market disposal. Best steam hards are in active request by all home consumers. Railway companies are making special efforts to secure stocks. There is also a fair demand for export, but of course control restrictions prevent more than a moderate tonnage being sent coastwise. Small slacks still show some sign of weakness, but there is a ready sale for other qualities, and for cobbles and nuts. In the household section there is considerable anxiety to secure supplies against the winter's requirements. Merchants complain that deliveries at depots are irregular and unsatisfactory. All classes of coke are in good demand with prices firm at the maximum level. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

RAILWAYS AND TRAMWAYS.—We are glad to announce that our French contemporary, *Les Chemins de Fer et les Tramways*, Paris, 2, Rue de la Pépinière, has now appeared again after an interruption of four and a half years, caused by the war. This is a monthly journal, dealing with railways and tramways, and with the industries connected thereto.

PEARL HARBOUR DRY DOCK.—We read in *Engineering News-Record*, New York, that the United States naval dry dock at Pearl Harbour, near Honolulu, was emptied for the first time on April 11 and found free from leaks. It is expected that the dock will be ready for service by July 1. It is designed for the largest vessels, being 1,040 ft. long by 148 ft. wide.

NATIONALISATION OF COAL MINES.—A resolution adopted by the London Iron and Steel Exchange, on Tuesday, the 17th inst., business being suspended for the purpose of considering the question, was as follows: "That this meeting of the members of the London Iron and Steel Exchange views with apprehension the suggestion for the nationalisation of coal mines, considering that such action will tend to increase the price of coal and thereby seriously affect manufacturing costs throughout the country." The proposer was Mr. C. L. Faulkner, of Messrs. Bolling and Lowe, Limited, and the seconder Mr. H. H. Hatherley, of the Wolverhampton Corrugated Iron Company, Limited.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Forge iron and the other lower qualities of Cleveland pig-iron are plentiful, and are offered freely for practically any delivery, but the better descriptions keep scarce, and the question of advancing them in price has been considered. There is, however, a strong feeling that any temporary advantage of such a step would be outweighed by more lasting disadvantages, and at present, at all events, there is no indication of any rise on the quotations which have ruled of late. There is a strong demand for foundry pig-iron, and there are home buyers thereof for supply to the end of the year, but most of the business passing is for delivery over the next three months, which is as far ahead as makers care to commit themselves. There is still very little doing on foreign account, but the granting of one or two export licences encourages the hope that business with customers abroad may expand in the near future. For home consumption, No. 3 g.m.b. Cleveland pig-iron and No. 4 foundry are 160*s.*, No. 1 is 164*s.* and No. 4 forge 158*s.*; and for export quotations are 5*s.* above these rates.

Hematite Iron.—Anticipated advances in East Coast hematite to cover the recent very considerable increased cost of production have not matured, and there now seems reason to conclude that for the present quotations will not be altered. Sellers, however, are less inclined to sell ahead, as when the higher prices of raw material become fully felt hematite rates now ruling would be quite unremunerative. What will happen in the near future is difficult to say, but makers apparently consider hematite prices already high enough for the best interest of the trade and are determined to keep them down as much as possible. Mixed Nos. are 190*s.* and No. 1 is 192*s.* 6*d.* for home use; and for export mixed Nos. are 195*s.* and No. 0 is 197*s.* 6*d.*

Foreign Ore.—Values of imported ore have reached unprecedented figures, but a feeling prevails that top prices have not yet been touched, as the large and growing demand cannot be fully met. Tonnage is by no means easy to arrange, for many shipowners are in no hurry to take ore cargoes so long as other trade is offering. Quotations depend upon the terms on which steamers can be chartered, and as 31*s.* has been paid Bilbao-Middlesbrough, best rubio has been put at 60*s.* c.i.f. Tees, but the latest fixture reported, Bilbao to the Tees, is 30*s.*, so that best rubio should not now be more than 59*s.*

Coke.—Coke keeps steady and firm. With a very ample supply meeting the large demand for local consumption considerable business is passing. Average blast-furnace kind is 39*s.* at the ovens, and low phosphorus quality 41*s.* 6*d.* at the ovens. Foundry coke for export is 70*s.* f.o.b. to neutrals and 65*s.* to the Allies.

Manufactured Iron and Steel.—There is a good deal of business passing in finished iron and steel. Home demand, particularly for shipyard requisites and railway material, keeps good, and inquiries from abroad continue on a fairly extensive scale. These industries, however, are not without disturbing features, foremost among them being labour troubles, and the still steadily-growing American competition. Export prices are not fixed, but they are rather above the following quotations, which govern the home trade:—Common iron bars, 20*l.* 10*s.*; marked bars, 23*l.*; strip iron, 21*l.* 15*s.*; ship rivets, 27*l.* 10*s.*; steel ship, bridge and tank plates, 17*l.* 15*s.*; steel angles, 17*l.* 5*s.*; steel joists, 17*l.*; steel hoops, 23*l.* 5*s.*; heavy sections of steel rails, 16*l.*; and galvanised sheets, 27*l.* 10*s.*

The Engineers' Strike.—The owners of the iron and steel works on Teesside have received with much surprise the decision of the engineers out on strike, to reject the offer of the employers to set up a Joint Committee to deal with the dispute. They take the view that the workmen have on this occasion adopted an unusual attitude by refusing to return to work until the matters in dispute had been discussed and negotiations entered into. Since the 47-hours' week came into operation the local executive of the engineers had applied to the iron and steel masters for a 44 hours' week. Conferences, the employers point out, had taken place, the result being that the employers on several occasions definitely promised that they would follow a national agreement to adopt a 44-hours' week. It is complained that instead of loyally awaiting the national settlement as others are doing throughout the country, the engineers in the iron and steel works on Teesside had refused to work night shift or overtime since March last.

MOTOR CARS IN SPAIN.—A diagram published in the *Bulletin of the Federation of British Industries* shows that in 1914 Spain imported 40 per cent. of her cars from France, 25 per cent. from Italy, 15 per cent. from Great Britain and 13 per cent. from the United States; 7 per cent. being Spanish built. The figures for 1918 were 22 per cent. from France, 12 per cent. from Italy, 7 per cent. from Great Britain and 29 per cent. from the United States; 30 per cent. being Spanish built.

THE LATE MR. JAMES VIPOND ELLIOTT.—We regret to have to record the death, on the 6th inst., of Mr. James Vipond Elliott, who had been the London representative for a great many years of Messrs. A. A. Jones and Shipman, Limited, manufacturers of machine tools, Leicester. Mr. Elliott was the oldest member of the staff, having been associated with Mr. A. A. Jones, the founder of the business, more than twenty years ago. He was a Lancashire man, and well known in engineering circles, both in Manchester and district, and in London.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—After careful consideration the Scotch steelmakers have advanced their prices, and the new quotations will only hold good until the end of July. Before the finish of that month the position will again be reviewed, and any further changes found necessary will be made in the existing rates. The present rise in prices is due to the advance in hematite iron, which is caused by the increased cost of the ore and the heavy freight demanded for bringing it here. With the change in prices consumers may now consider new projects, but delay in placing contracts may be prejudicial, as order books generally are already well filled, and during the month of July the various works close down for the usual 10 days' holiday, making a short month of only three weeks. The actual fresh business during the past week has not been too heavy pending the readjustment of prices, but an immediate improvement is now anticipated. The pressure for deliveries has shown no falling-off, and makers have been turning out a big lot of stuff. The home demand for ship plates continues, and inquiries for shipment are also exceedingly good, but there is not very much left over as available for the foreign market once the local consumers are supplied. In sectional material there is not so much business going through, and some of the mills could be doing with more orders. Steel sheets show no sign of a decreased demand, but for galvanised sheets there is much need of an improvement, as this branch of industry is rather quiet. The general export trade is quiet, although inquiries have recently been quite good, but with prices again up it remains to be seen whether the preference of some markets for Scotch steel will still hold when any material is available for shipping. The official list of prices now agreed to by the Scotch steel makers is as follows: Boiler plates, 21*l.* per ton; ship plates, 18*l.* 5*s.* per ton; angles, 17*l.* 15*s.* per ton; small flats, rounds and squares, 20*l.* 5*s.* per ton; forging blooms and slabs, 19*l.* 15*s.* per ton. These prices are all net delivered Clyde district, and all other present conditions will remain unaltered. During July the export rates for boiler plates, angles, &c., small rounds, flats and squares will be the same as for the home market, while ship plates are to cost 18*l.* 10*s.* per ton, all prices being for net cash, f.o.b., Scottish ports, and subject to the list of extras intimated as at May 1, 1919.

Malleable Iron Trade.—In the West of Scotland malleable iron trade there is little fresh to report, and steady employment is being maintained. Deliveries are good and makers seem in rather a better position to meet the demand, which is perhaps not quite so pressing. The home market continues to absorb the most of the output, and the export trade is expanding slowly. There is a steady and growing demand hor agricultural sections and engineering material.

Scotch Pig-Iron Trade.—The demand for all qualities of Scotch pig-iron continues strong, and pressure for deliveries is still heavy. Prices have made a sharp rise, and that may cause a slight check in new business, but that will only most probably be of a temporary nature, as every ton which can be turned out for some time to come will be required for work on hand. Two things are responsible for the present advances, the increased price demanded by the sellers of ore, and the heavy freight from Spain, the latter being now round 30*s.* per ton. The current price of hematite iron is quoted at 10*l.* 3*s.* per ton, and even at that figure producers are unable to meet the demand as the local steel makers are keeping up a steady pressure for deliveries. For forge and foundry iron the demand is also good, and No. 1 foundry iron has now reached an extremely high level, and over 10*l.* per ton is being asked. The amount of pig-iron exported from the Clyde during last week totalled 1,450 tons, all foreign, as against 15 tons, coastwise, for the corresponding week of last year.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—The recommendations of the Coal Commission for Nationalisation of the mines came as a surprise to the commercial community. It was expected that the miners' representatives would be for nationalisation, but it was not anticipated that the chairman would have been so decisive in his opinion on the matter. As a whole the matter has not been very much discussed by operators, as they feel that it is not wise to express any definite opinions yet, and are content to allow matters to develop. There is, however, a strong feeling against nationalisation as it is considered impracticable. Colliery owners, investors, and traders, will be considering almost immediately what steps shall be taken in the matter, and it is not believed that Parliament will authorise the proposals made by the Commission. Despite a continuance of the strike of Messrs. Cory Brothers' clerks and stoppages in the coalfields, outputs during the past few days have increased to a small extent. The visit of the Royal Show to Cardiff is responsible for a greater proportion of absenteeism at the mines, but notwithstanding this, it is expected that now that the Commission has given recommendations in favour of nationalisation, the miners will at any rate for a time, work harder, and production is therefore likely to improve, at least temporarily. The Prince of Wales yesterday visited the Rhondda and descended the Cymmer pit of Messrs. Insoles, Limited. There is a good inquiry for all classes of coals, and exporters have ample supplies of tonnage at their disposal. In fact, many of the vessels now in dock have been waiting over a week for supplies. The dock boatmen, pilots and riggers have put into operation their threat to reduce their hours of work in an effort to force the employers to grant them their application of a 20 per cent. increase in their war bonus on total earnings, and this will further reduce the export capacity of the various ports. The men are now working on the same hours as the trimmers, with the result that vessels cannot be shifted about in the docks during 8 hours of the day. Prices for all descriptions of coal are very firm but irregular, and dependent on the individual position of buyer and seller. For allied countries 55*s.* is being readily paid for best Cardiff large coals, and some sellers are asking up to 60*s.* Smalls are also very tight, with 45*s.* quoted for the best descriptions and 43*s.* 6*d.* readily paid. For spot shipment buyers are able to obtain concessions of from 2*s.* 6*d.* to 5*s.* on these prices, as some collieries are eager to secure a release of wagons. Few buyers are, however, in a position to take advantage of this opportunity. Generally, collieries are fully stemmed over the next fortnight, and in some cases are refusing to give quotations.

Newport.—Monmouthshire coals, both large and small, are considerably below the requirements of buyers, and prices, though irregular, are firm. For the better class of Monmouthshire large coals, 55*s.* is being paid, and for smalls from 37*s.* 6*d.* to 43*s.* 6*d.*, though sellers are quoting up to 5*s.* in excess of these figures. There is practically no business passing for neutral countries owing to the inability of merchants to get coals released on account of the pressure of allied requirements.

Mond Nickel Works partly Closed.—The directors of the Mond Nickel Company, Limited, have decided, owing to the almost complete stagnation of trade and the consequent accumulation of stocks, to close down three-quarters of the works. About 900 men will be thrown out of work, and 400 will be retained; these will be selected from long-service employees and discharged service men.

Swansea General Cargo Workers' Tariff.—The Joint Committee appointed to formulate a tariff for general cargo work has practically completed its task. The new tariff has been arranged to regulate the wages of the general cargo workers at the port, and is complete except for the arrangement of a few minor points. Under the new tariff all "extras" over which the recent strike originated, are eliminated, and it is confidently believed that if the spirit as well as the letters of the agreement are observed, a big step has been taken towards ending the trouble that has occurred in the past. Flat rates have been arranged to suit every conceivable situation that might arise in regard to the nature of the cargoes to be unloaded or loaded, and the type of vessel, &c.

DISPOSAL OF GOVERNMENT STORES.—The second number of *Surplus*, the official organ of the Surplus Government Property Disposal Board, Ministry of Munitions (see page 780 *ante*) has now appeared. This contains 96 pages of illustrated information on the material available, and states how this will be disposed of. The pamphlet (price 3*d.*) is on sale at all bookstalls and newsagents.

TRANSATLANTIC RADIO-RECEPTION.—During the latter part of the war the United States Signal Department entered into an elaborate inquiry into the causes which might interfere with radiotelegraphic communication across the Atlantic. The primary object was to find the best localities for receiving stations in the United States. For this purpose the X interferences had to be studied in particular, that is to say, the disturbances of radio signals by causes which may broadly be described as meteorological and not comprising interference by other radio signals and by the inductive effects of power stations. The name X was adopted for such disturbances by the British Association Committee for Radiotelegraphic Investigation, which has collected many valuable data. An account of the work of the United States Radio Development Section was given by Major Charles A. Culver, who organised the investigation, in the May number of the Journal of the Franklin Institute. A considerable number of stations were selected, near the Atlantic coast and in the interior; some stations proved unsuitable and were replaced by others. At all the stations records of the X and of signal audibility were kept, and copies of the trans-Atlantic traffic from the other side (three English, four French, one Italian station, also Nauen in Germany) were taken daily and forwarded to the Washington office, while the simultaneous meteorological records were carefully studied. Various anti-X devices were also tried; it was known that atmospheric disturbances affect high vertical antennæ far more than low horizontal antennæ, and this was confirmed, but to put the antennæ under cover (in buildings) proved of no advantage. It would appear that the local interference is complex and has a local origin as well as a remote origin; the X intensity is little affected by the barometer, and varies inversely as temperature and wind, and directly as the relative humidity and as the horizontal magnetic intensity; it has also its diurnal period. But a receiving station may be good or bad in different seasons, and to different transmitting stations; two stations only a mile apart may differ strongly; one station receives best from Lyon, another from Nauen; geographical distance itself is not the chief factor; yet North-Eastern Maine, which comes nearer Europe than other parts of the States, seems best suited for a receiving station, though the neighbourhood of Washington will do quite well. Little radiotelegraphic energy passes beyond the Great Lakes, yet portions of messages, which coastal stations fail to pick up, are sometimes received inland. The paper by Major Culver (50 pages) contains many interesting points, but the time has hardly come yet for drawing general conclusions.

NOTICE OF MEETING.

THE ROYAL METEOROLOGICAL SOCIETY.—Tuesday, July 2, Summer Meeting of the Society at Kew Observatory, Richmond. The Observatory will be open at 3.30 p.m. Programme of arrangements: (1) Demonstration of a Portable Wireless Apparatus for use in the Location of Distant Lightning Flashes, by Mr. R. A. Watson-Watt, B.Sc., F.R.Met.Soc.; (2) Pilot balloon ascents will be made from the Observatory grounds; (3) the president (Sir Napier Shaw) will exhibit two diagrams showing the motion of air in travelling depressions; (4) an exhibition will be held of autograph records of the Observatory, photographs of clouds and other meteorological phenomena, and some recent meteorological instruments will be on view.

SOCIETY OF GLASS TECHNOLOGY.

THE June meeting of the above society was held at the University, Sheffield, on the 18th inst., the president, Mr. S. N. Jenkinson, in the chair. The secretary paid a touching tribute to Mr. Crowther, in whose death the society have suffered a great loss. Mr. Crowther was one of the original members, and played a considerable part in the foundation of the society, and had always taken a very keen interest in its doings.

Mr. S. N. Jenkinson addressed the meeting on "*Impressions of a Recent Tour of the German Glass Factories.*" Mr. Jenkinson prefaced his remarks of his experiences in Germany by appealing to all members of the society to pull together as in the past, and to endeavour by all means in their power to increase the prestige of the society. During his tour in Germany he visited Silesia, Saxony, Saxe-Weimar, and other districts, and investigated conditions in several works, particularly glass factories. The size of the glass industry in Germany in pre-war days can be judged from the fact that in 1913 they exported glass to the value of 123,000,000 marks, and pottery to the value of 94,000,000 marks. This amount means that 75 per cent. of their output was exported. It can be realised, therefore, that the outbreak of war caused the shutting down of many German glass factories during 1914–15. The policy during 1915–16 in Germany was to reopen several of the factories, and allow one furnace in each works to be kept going, and a scheme was inaugurated whereby finance in the industry was pooled. At the present time very little production of glassware is taking place, due largely to the lack of coal, and the state of transport. Their stocks are very low. Throughout the visit he was very much impressed by the fact that all the plant in the works was kept in the highest pitch of efficiency, so that immediately opportunity came a high rate of production would follow. This fact will have to be taken into account by British manufacturers. Out of some 132 furnaces which he made inquiries about, only eight were working.

Mr. M. W. Travers, D.Sc., F.R.S., then gave a short account of "*Some Experiments with a Gas-Fired Pot Furnace.*" The author gave a description of furnaces which had been used in producing chemical glassware, and advocated burning the gas from the producers in front of the pots, and taking the burnt gases out of the furnace at the back. He illustrated his remarks by means of several lantern slides. Considerable discussion followed the paper.

Dr. Turner then read a paper on "*The Properties of British Fireclays Suitable for Glass Works Use. Part I. The Variation of Shrinkage, Density and Porosity with Temperature.*" (Preliminary communication.). By Edith M. Firth, B.Sc., F. W. Holden, B.Sc., and W. E. S. Turner, D.Sc. This paper was well illustrated by assemblies of fireclay blocks showing the behaviour of various fireclays under the tests outlined by the authors. The paper is the first communication of a research carried out under the auspices of the Refractories Research Committee of the Society.

A third paper entitled "*The Examination of Optical Glass in Relation to Weathering Properties,*" by A. V. Elsden, Oswald Roberts and H. S. Jones, was taken as read, and will be published in the Journal of the Society in due course. The above meeting ended the session. The first meeting of the new session will take place during October.

CHARCOAL PIG-IRON.—Our attention is called by the Charcoal Iron Company, Limited (late Harrison Ainslie and Co., Limited), Backbarrow, near Ulverston, to the fact that their furnace has been in blast about six weeks making "Lorn" charcoal cold blast iron.

UNITED STATES COAL.—According to *The Iron Age*, Mr. J. D. A. Morrow, of Washington, vice-president of the National Coal Association, has stated that daily records are being kept of the output of the mines. There is, he added, every indication of a coal shortage next winter. Up to May, 1917, there had been a falling-off in production, as compared with 1918, of about 30 per cent. Europe will need at least 54,000,000 tons of coal this year. The coal to supply this demand is already beginning to move across the Atlantic.

EXCESSIVE PRICE FOR YELLOW PINE.—The Controller of Timber Supplies gives notice to all concerned that in the event of excessive prices for yellow pine being continued he will have no option but to dispose of Government stocks direct to consumers at prices not higher than the late maximum prices. He requests any firms who are asked for yellow pine prices higher than the late maximum prices to send full particulars to the Assistant Controller of Timber Supplies, Branch 5, 80, Newman-street, Oxford-street, London, W. 1.

EXHIBITS AT THE ROYAL AGRICULTURAL SOCIETY'S SHOW AT CARDIFF.

(*For Description, see Page* 836.)

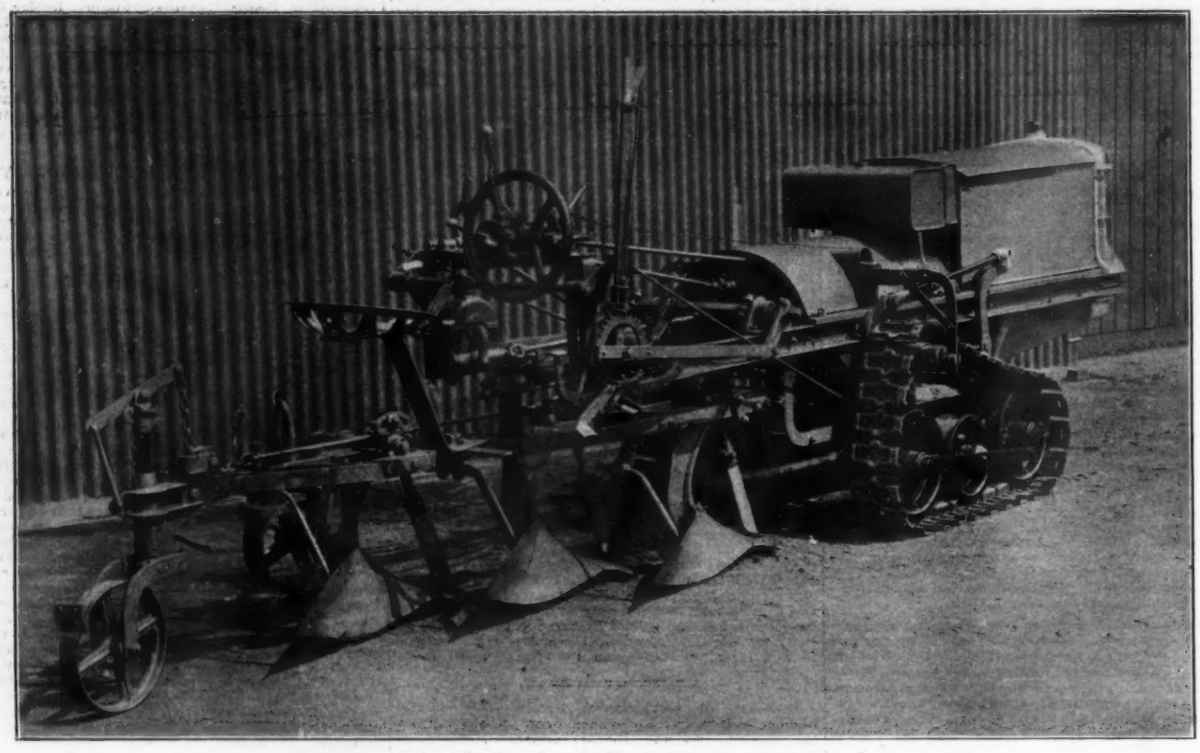


FIG. 5. THREE-FURROW MOTOR PLOUGH; MARTIN'S CULTIVATOR COMPANY, LIMITED, STAMFORD.

NAVAL ENGINEERING. [THE NEWMAN MEMORIAL PRIZE.—The only prize available for naval engineer officers is the Newman Memorial Prize. Owing to the abandonment of the old system of training engineer officers and on account of the war no award of this prize has been made for some years. A recent order, however, gives particulars of how the accumulated funds are to be allotted for prizes for officers who have passed through Osborne and taken up (E.) duties, and after 1920 the prize is again to be awarded annually on the result of the courses now in existence at Keyham for lieutenants (E.). The prize was founded many years ago in memory of Edward Newman, R.N., who died in December, 1882, while chief engineer of Portsmouth Dockyard. Newman's death was supposed to be indirectly due to the shock he received on the occasion of the terrible boiler explosion on H.M.S. Thunderer, July 17, 1876, the most disastrous boiler accident in naval annals. The ship was doing a full-power trial in Stokes Bay when one of the boilers blew up, causing the loss of 38 lives, while 77 other persons were injured. The inquest, which ran to very great length, went to show that the stop valve was probably shut, the pressure gauge out of order and one of the ponderous dead-weight safety valves jambed in its seating. The whole of the evidence is given in ENGINEERING, vol. xxii.

SELENIUM APPLICATIONS.—In an article on selenium and its applications, published by L. Ancel in the Journal *Chimie et Industrie*, of March last, attention is drawn, among other things—mostly well known—to the use of selenium cells as smoke recorders in chimneys. A selenium cell is mounted on one side of a chimney or flue; on the opposite side is fixed a lamp. The amount of light falling upon the selenium and hence the resistance of the cell will depend upon the density of the smoke in the flue; the fire can therefore be controlled by the galvanometer records. Ancel describes the device very briefly; he mentions that the cell should admit of easy access so that the smoke settling on the glass cover of the cell may be wiped off, and also that selenium cells are very sensitive to infra-red heat rays as well as to light. It is not settled yet, in fact, whether the light effect on selenium is not essentially a heat effect; that point would in a way militate against the reliability of the selenium cell to act as smoke recorder. We should also like to hear more about the other novel application of selenium cells, mentioned by Ancel, for controlling the contact sulphuric acid process by the degree of the transparency of the gases in the reaction tube. Ancel, however, does not give any technical data. The journal above-mentioned is the new organ of the Société de Chimie Industrielle; the first number was published in June, 1918.

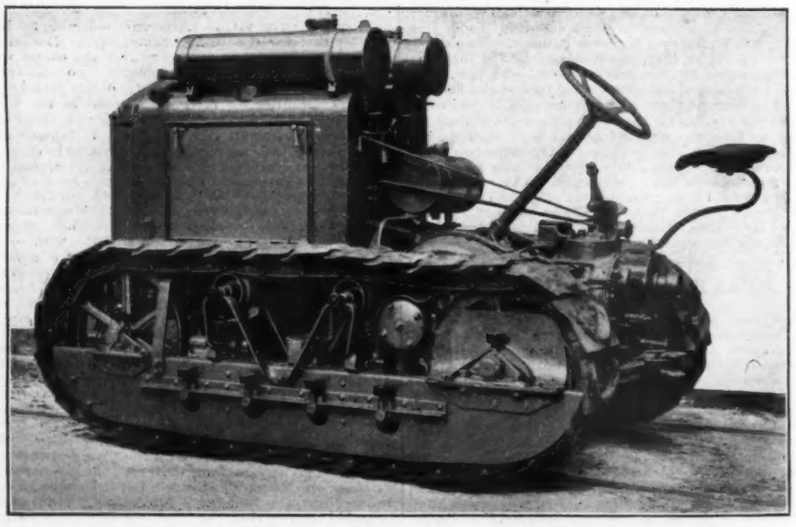


FIG. 6. CATERPILLAR TRACTOR; MESSRS. CLAYTON AND SHUTTLEWORTH, LIMITED, LINCOLN.

JAPANESE SHIPPING.—According to the *Japan Advertiser*, the vessels registered in Japan at the end of December, 1918, consisted of 2,641 steamers, aggregating 2,310,959 tons, and 12,431 sailing vessels of 857,556 tons. Steamers over 1,000 tons numbered 616, having a gross tonnage of 1,859,349 tons. In 1917, the shipbuilding yards in Japan numbered 145, but about 40 of the smaller shipyards have since been closed.

THE ASSOCIATION OF BRITISH MOTOR AND ALLIED MANUFACTURERS, LIMITED.—At the annual general meeting of this association, held recently, Mr. H. C. B. Underdown was unanimously re-elected president of the association, and Mr. Bernard Caillard unanimously re-elected vice-president. Mr. Underdown is chairman and managing director of Commercial Cars, Limited, Luton, and a director of Messrs. Sheffield Simplex Motor Works, Limited. Until recently he occupied the position of Controller of Agricultural Machinery at the Ministry of Munitions. Mr. Caillard is a son of Sir Vincent Caillard, Bart., and is a director of Wolseley Motors, Limited, and managing director of the British Lighting and Ignition Company. The Research Association of British Motor and Allied Manufacturers is now in course of formation and definite promises of support have been received from a large number of the leading firms. It will be governed by a council assisted by a Committee of Research. The work of the Research Association will fall under two heads: Research proper, and the collection and organisation of scientific information bearing upon all questions which may subsequently become the subjects of research.

THE RITCHIE UNIT SYSTEM OF CONCRETE SHIPBUILDING.

(*For Description, see Page* 825.)

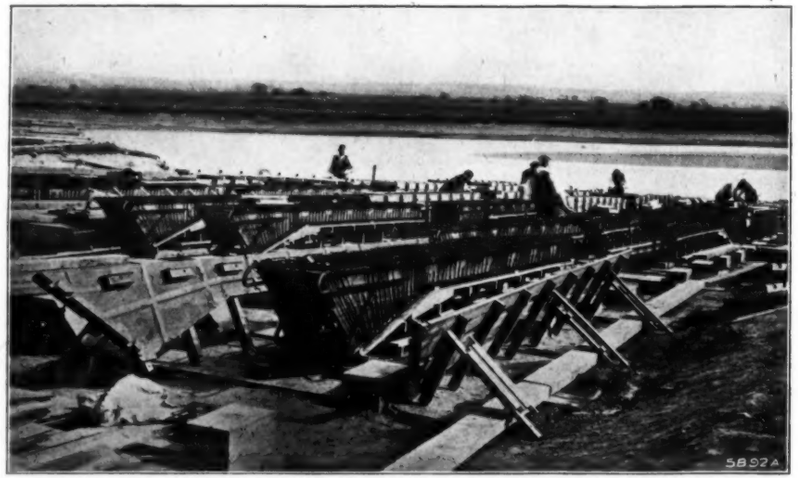


FIG. 2. REINFORCEMENT ASSEMBLED FOR CASTING SHELL UNITS.

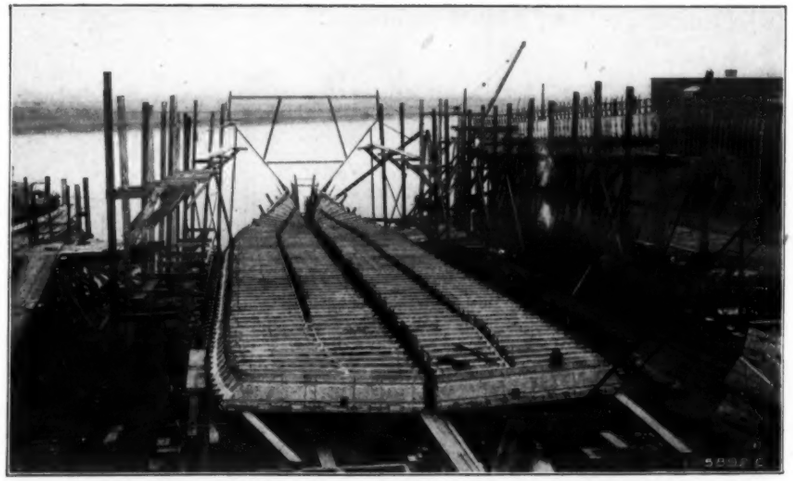


FIG. 4. BOTTOM UNITS ASSEMBLED ON BUILDING BERTH.

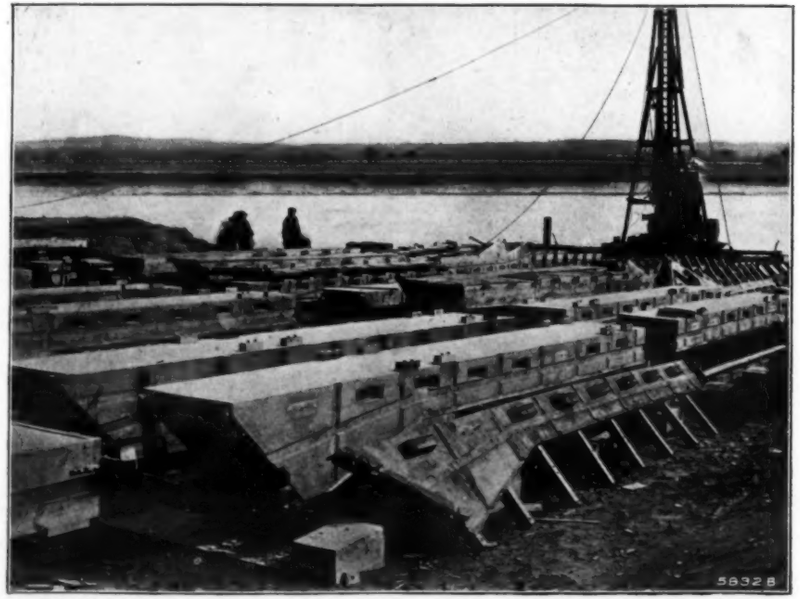


FIG. 3. SHELL UNITS AFTER REMOVAL OF SHUTTERING.

FIG. 5. SIDE UNITS ASSEMBLED ON BUILDING BERTH.

(*To face page* 826.)

THE RITCHIE UNIT SYSTEM OF CONCRETE SHIPBUILDING.

(For Description, see Page 825.)

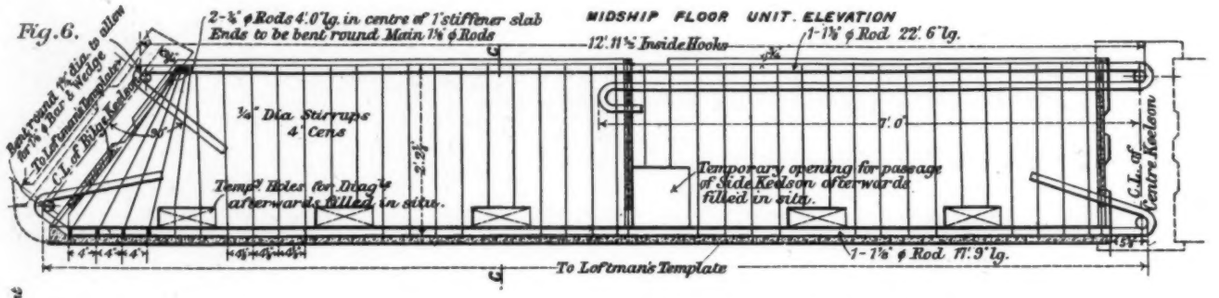


Fig. 6.
MIDSHIP FLOOR UNIT. ELEVATION
2-¾" φ Rods 4'.0" lg. in centre of 1' stiffener slab
Ends to be bent round Main 1⅛ φ Rods
12'.11½" Inside Hooks
1-1⅛" φ Rod 22'.6" lg.
¾" Dia. Stirrups 4" Cens
7'.0"
Temp.y Holes for Diag.ls afterwards filled in situ.
Temporary opening for passage of Side Keelson afterwards filled in situ.
C.L. of Centre Keelson
1-1⅛" φ Rod 11'.9" lg.
To Loftman's Template

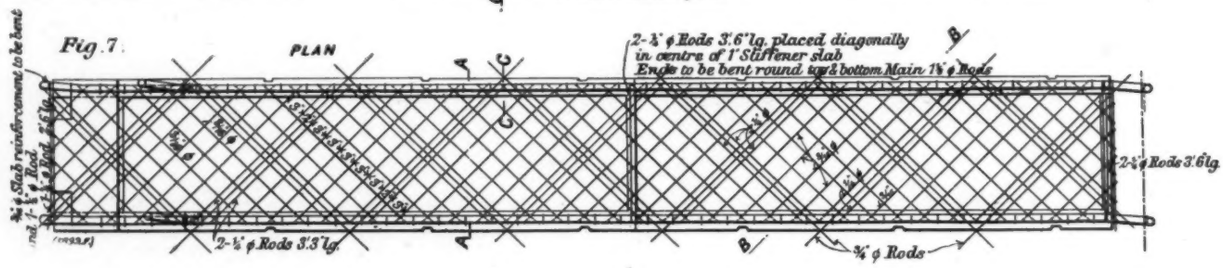


Fig. 7.
PLAN
2-¾" φ Rods 3'.6" lg. placed diagonally in centre of 1' Stiffener slab
Ends to be bent round top & bottom Main 1⅛ φ Rods
2-¾" φ Rods 3'.6" lg.
2-½" φ Rods 3'.3" lg.
¾" φ Rods

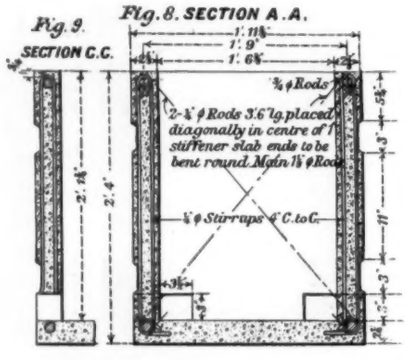
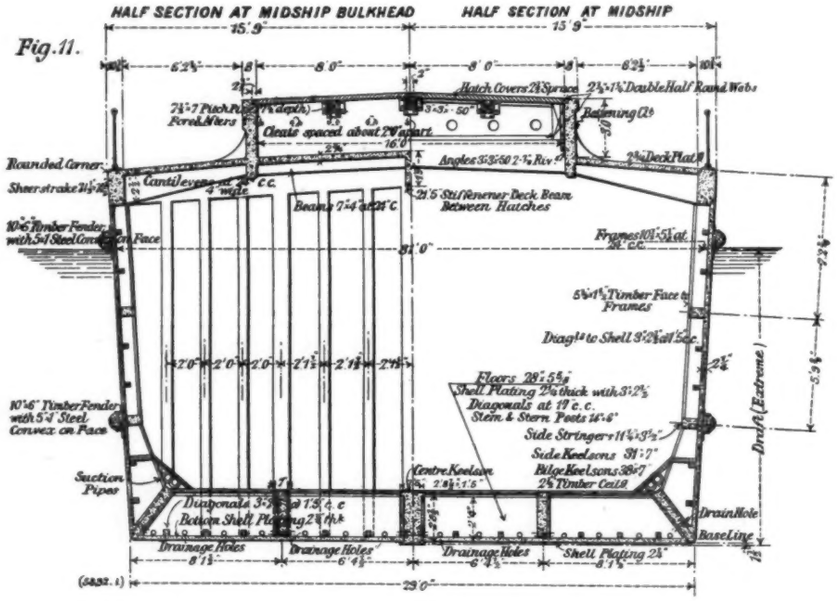
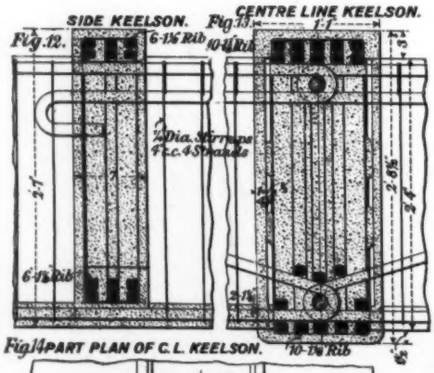
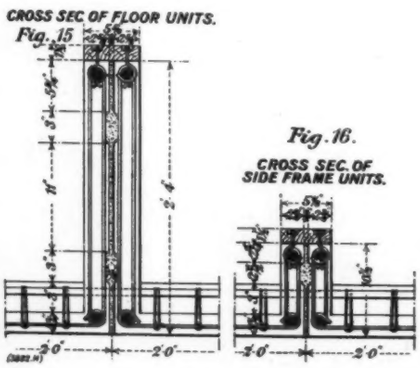
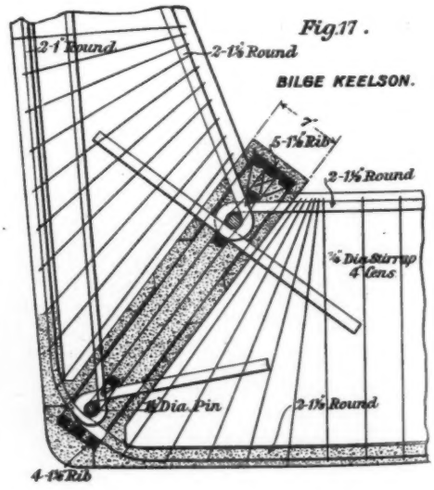


Fig. 9.
SECTION C.C.
Fig. 8. SECTION A.A.
⅝" φ Rods
2-¾" φ Rods 3'.6" lg. placed diagonally in centre of 1' stiffener slab ends to be bent round Main 1⅛ φ Rods
¼" φ Stirrups 4" C. to C.
Fig. 10. SECTION B.B.
⅜" Dia. Wire Stirrups 1'.3" lg. @ 3' Cens
¾" Rod.
¾" φ Wire 3' C.C. both ways in Cen. of Slab
¾" φ Wire
2-¾" φ Rods 3'.3" lg.









THE U.S. NAVAL AIRCRAFT FACTORY, PHILADELPHIA, PA., U.S.A.

(*For Description, see Page* 826.)

FIG. 5. THE HULL AND ASSEMBLY SHOP OF THE ORIGINAL WORKS.

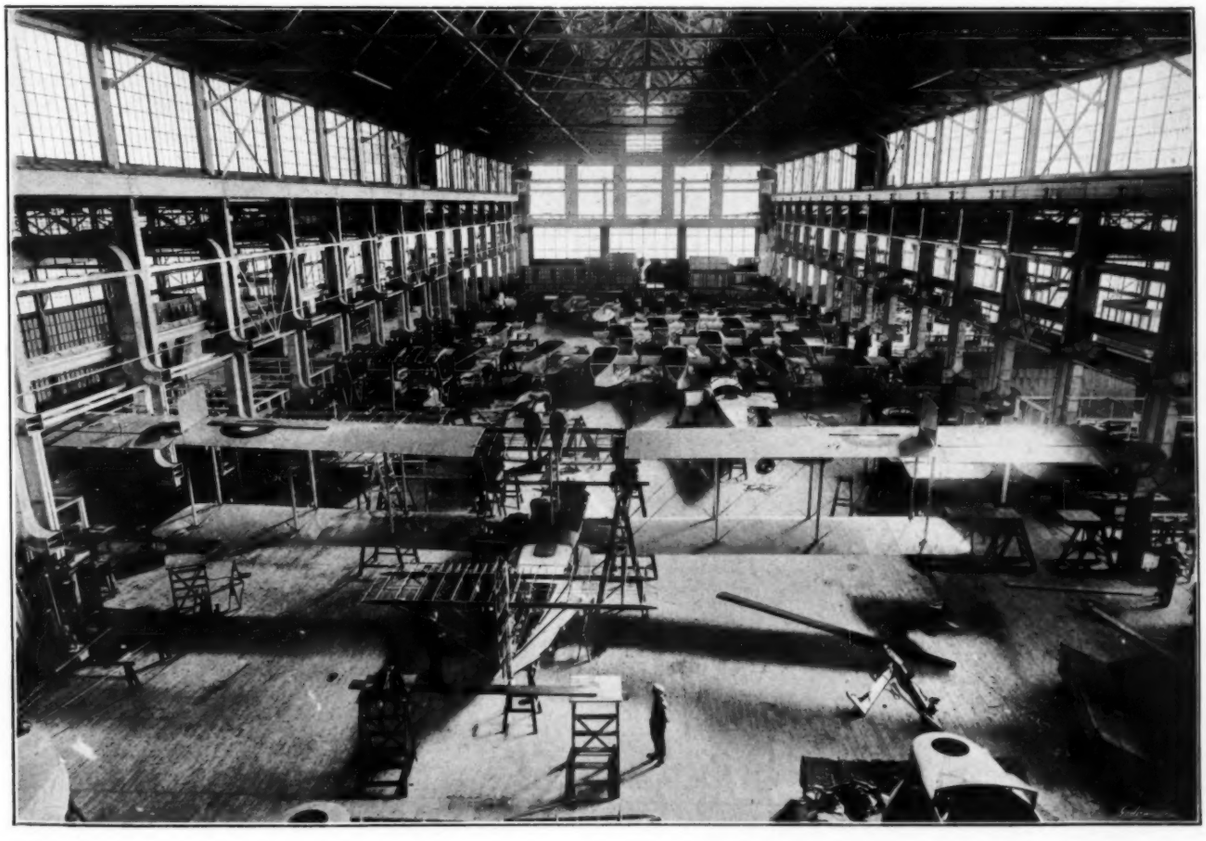


FIG. 6. THE ASSEMBLY SHOP OF THE LATER FACTORY.

THE U.S. NAVAL AIRCRAFT FACTORY, PHILADELPHIA, PA., U.S.A.

(*For Description, see Page* 826.)

FIG. 7. THE ASSEMBLY SHOP.

FIG. 8. THE ASSEMBLY SHOP.

(*To face page* 827.)

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication, and certainly not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3883 and 8598 GERRARD.

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With Two One-Page Plates of the RITCHIE UNIT SYSTEM OF CONCRETE SHIPBUILDING, and Two One-Page Plates of the U.S. NAVAL AIRCRAFT FACTORY, PHILADELPHIA, PA., U.S.A.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 841.

ENGINEERING.

FRIDAY, JUNE 27, 1919.

THE COAL COMMISSION REPORT.

THE result of the inquiry by the Coal Industry Commission is just what one would have expected in view of the composition of the Commission and of its method of procedure. The inquiry was conceived in haste in order to clear what the chairman, Mr. Justice Sankey, refers to as "the present atmosphere of distrust and recrimination." The composition of the Commission was faulty because the membership was too great and, being largely representative of two antagonistic forces, led to flippancy, suspicion and recrimination throughout the proceedings. Indeed, there was a complete lack of that judicial calm which is essential to the solution of problems of such national importance and involving such great difficulties. The result conforms to this procedure, as there is an absence of reasoned and informing guidance to Parliament as to future legislation. We have separate reports from the two contending parties, an independent report from Sir Arthur Duckham and a report from the chairman, Mr. Justice Sankey. In none of these is any attempt made to analyse the evidence given by witnesses. Indeed, there is little that is convincing in favour of the far-reaching general and conflicting recommendations made.

It is recommended in practically all the reports that the State should acquire all coal royalties by the payment of "a fair and just compensation to the owners" although the miners would confine this recompense only to owners deprived of their means of livelihood—which is suggestive of charity and not justice. This purchase by the State is to include any coal, the existence of which may be uncertain but suspected, as well as all underground wayleaves. Nationalisation of the whole industry, including distribution, is also recommended in some of the reports, but there is no clear and convincing argument that this nationalisation will even improve, far less remove, "the present atmosphere of distrust and recrimination." Throughout the whole of the inquiry, and indeed running through the present-day demand for State acquisition of commercial and industrial undertakings, there is confused reasoning. We do not propose to consider for the moment whether or not such State purchase is desirable, but it is of the utmost importance that a line should be drawn between nationalisation and syndicalism; because many who look to nationalisation for improved efficiency are encouraged in their acceptance of the idea by their desire to see equality of treatment. Syndicalism, which is advocated now under the guise of State ownership, is, on the other hand, only a transfer from private ownership to ownership by the workers. There can be no doubt that the miners, like many other sections of the community, are seeking to achieve this result, and however much the framers of State ownership schemes may seem to try to safeguard the interests of the State as a community the ultimate result would be very serious for all consumers of the commodities thus produced under syndicalism. The very conditions which made the appointment of the Commission necessary showed clearly that the interests of the consumers were being entirely neglected, and in the elaborate schemes that have since been prepared this attitude of mind still prevails.

The main desideratum is, as Mr. Justice Sankey put it, "the provision of a cheap and adequate supply of coal, which is essential to the comfort of individuals and to the maintenance of the trade of the country," and it is recognised on all hands that the present conditions are unsatisfactory. There are nearly 4,000 owners, many of them working pits which give unsatisfactory financial results. But Mr. Justice Sankey admits that most of these owners are reasonable, although some "are a real hindrance to the development of the national asset." It is generally accepted that some approach to the unification of industry is desirable, and one-half of the members of the Commission favour the division of the country into districts by the amalgamation or combination of the mine owners in those several districts working under a Ministry of Mines, whose main interest would be to conserve the interests of the State, and therefore of the consumer, while ensuring the application of modern methods to the conduct of research, the establishment of safety appliances, and generally the betterment of the condition of the worker. This is the alternative to nationalisation, and it gives what even Mr. Justice Sankey seems to fear State purchase would not give—a minimum of opportunity for bureaucracy to handicap our "national key industry, upon which nearly all our industries depend." Moreover, it overcomes many of the difficulties which are adumbrated rather than enunciated in Mr. Justice Sankey's scheme. For instance, there is the case of mines forming part of composite undertakings. For some time there has been a tendency for iron and steel companies, and, indeed, for other industrial concerns, to own their own mines and use their own coal. Mr. Justice Sankey considers that if, in the opinion of the arbiter, the severance of such undertaking cannot be economically or commercially effected, the State should have the right to compel the owner to sell the whole undertaking. This, it will be seen, is a very big proposition. Again, it is stated that it is a matter for careful consideration whether the coke and by-product industry, which is at present only in its infancy, should not be allowed to remain in private ownership, although this proposition is without prejudice to the powers for acquiring composite undertakings of which a coal mine is a part.

Mr. Justice Sankey's scheme of management is based on the broad lines of the Whitley Committees. There is to be a Local Mining Council, consisting of ten members; the manager, under-manager and commercial manager being *ex officio* members, with four members elected by ballot by the workers in or about the mine, and the remaining three by the District Mining Council, to which we shall refer later. This local council is to meet fortnightly to advise the manager on all questions concerning "the direction and safety of the mine." The certificated manager, however, is to be responsible for everything, but will not be personally liable for conforming to any lawful order for safety made by the District Mining council. No light is shed on what is to happen if the manager does not accept the advice given on all questions concerning "the direction" of the mine. But it is provided that no workman will, in consequence of any dispute, join in giving any notice to determine his contract, nor will he be open to cease work unless and until the question in dispute has been before the District Mining Council, and this council has failed to settle the dispute. It is exceedingly problematical whether this would obviate strikes in the future any more than the corresponding machinery which can now be brought into action in connection with the Ministry of Labour. When men have reached a certain stage in discontent no machinery will prevent them from breaking an agreement. Another noteworthy point is that it is recommended that the workers at each mine shall be entitled to output allowance, to be ascertained in any approved manner and divided among them half-yearly. Whether this will arrest the steady decrease in the output per man time alone will show, but in the past such deferred bonuses have not had the same effect as honestly fixed piece work or bonus rates payable each week or each fortnight. It is incumbent that we should maintain our output at or over 250,000,000 tons per annum, a rate which is certainly not now being attained, and, as Mr. Justice Sankey very justly states, "if the output per man continues to go down the supremacy of this country is in danger."

The district mining council, according to the recommendation, is to number 14, and the object is "to prevent the bureaucratic running of industry." The country is to be divided into 14 areas, and the district mining council, subject to the direction of the Minister of Mines, is to manage in its district the entire coal extraction, the regulation of output, the discontinuance of or the opening out of mines, trial sinkings, the control of prices and the basis of wage assessment, and, finally, the distribution of the coal. For this latter, however, it is to make arrangements with distributing authorities, societies or individuals, and a suggestion of the trend of the times is indicated by the proposal that in country districts, if permissible, the local railway stationmaster will have charge of the sale and distribution of inland coal. The district council is to consist of a chairman and vice-chairman, to be appointed by the Minister of Mines, and of 12 others, four of whom will represent the consumers, two of these the iron and steel trades in districts where these trades predominate, and two in shipping districts to represent coal exporters. Two others will represent mining engineering and two the commercial side of the industry in connection with the purchase of material and the sale of output. The district council is to have a commercial committee and a commercial manager. Here again a clause is introduced against striking in the district before the council and the National Mining Council have considered the matter or have failed to settle the dispute. This is a scheme obviously alternative to the idea of organisation of the mines in each district under a combination—statutory or otherwise—whereby the more prosperous mines would assist those in which financial success may not be so easily achieved.

The National Mining Council is to be formed of members elected by the district councils, one member being given to each for every 5,000,000 tons of output, provided that every district shall elect at least one member. The members are to be elected for three years and to meet once a year or at such other times as may be determined by the Minister of Mines. A standing committee of 18 is to be selected, six of whom shall retire each year and shall not be eligible for re-election for the following year. It is obviously the intention that the National Council will include miners in its membership, but it is not intended that any salary shall attach, although members will be entitled to travelling expenses. The standing committee is to include six such workers and six consumers, the remaining six representing the technical and the commercial side of the industry. The Minister of Mines, it would appear, however, is to be supreme, as he can, after consulting the standing committee, veto any resolution come to either by a local or a district council; but in the event of his so doing he must publicly state his grounds for acting. It will be seen that the Minister of Mines has very great power, and in all legislation due regard must be given to the complexion of possible future governments. Moreover, it is notorious that in all ministries the permanent officials become, by the operation of the regulations under which they work, more or less bureaucrats, and must exercise great power even over Ministers and standing committees. Mr. Justice Sankey seems to have had that in mind, as he inserts the clause—"It being of vital importance that the Mines Department should be managed with the freedom of a private business, the present civil service system of selection and promotion by length of service, of grades of servants, of minuting opinions and reports from one servant to another, and of salaries and pensions, shall not apply to the servants attached to the Mines Department." However unsatisfactory the civil service system may be we would like to have had more constructive suggestions regarding this proposed innovation. Indeed, this is only another instance of the incompleteness—one might almost say the sketchiness—of the treatment of this highly important question, and further evidence is found in the casual way in which the export trade is dealt with, as it is indicated simply that any person shall be entitled to purchase coal for export from any mine, in the same way as he would have been entitled had such mine remained in private ownership; but the exporter to whom coal is sold for export shall divide all profits over 1*s.* per ton sent with the district mining council.

Much more might be written by way of criticism, but the scheme has yet to be considered by the Government, and if they mean to take action they will have to embody their ideas in a Bill in Parliament, so that it is preferable to wait until this step has been taken before discussing the matter further. It is to be hoped, however, that Parliament will sift every detail of any such measure, if it is produced, in order that this great key industry may not be adversely affected by a proposal which has at its very root a change of ownership not so much in the interests of the State as of the miner.

THE LINK BETWEEN SCHOOL AND WORKSHOP.

EDUCATION, it may be said without offence, has suffered somewhat from admirable phrasing. Stein, to whom German schools owed much of their character, took as his fundamental principle that "every power of the soul is to be unfolded," yet, be it noted, he emphasised the "advantage to society of cultivating fitness for special functions." The first phrase and its variants lulled to sleep our philosophising educationists and the teaching hierarchy; the full significance of the practical saying was but dimly discerned. James Mill, the utilitarian, declared that the end of education was "to render man an instrument of happiness to himself and others." Mere agreement with this sentiment is futile, and it fell to his distinguished son to point out that this aim did not preclude special preparation for the maintenance and even the extension of material progress. But drowsy contentment with the trammels of custom, encouraged by high-toned and ineffective references to harmonious evolution has long held sway, and, it is only in these latter days that a general awakening has come. The happiness sought by the Benthamites rests, in the last resort, on successful production. For that success we must have judicious selection and well-ordered preparation of workers. To that end the curricula and the spirit of the schools will have to be directed, and, from a closer and more mutually helpful union of classrooms and workshops, there will come advantages to the individual and the State.

Recently Sir William Whitla, M.P. (Queen's University), presiding at the jubilee of an outstanding Irish secondary school—the Methodist College, Belfast—spoke in no uncertain way of the need for vast changes in educational aims and methods. The war, he said, had changed the outlook and had impressed upon every thinking man the enormous importance of strenuous development of school work and especially of scientific training in secondary schools. This doctrine we preached in these columns long before premonitions of devastating conflict among the nations had disturbed the public mind, and so we welcome the winged words of the distinguished Professor of Medicine as diagnostic of an awakened consciousness, in professional classes, of the nature of past defects in education, and as supplying the essentials of an appropriate prescription. Yet, as we suggest, the treatment recommended has recourse to no novel synthesised ingredients. Its virtue lies in its being an imprimatur from an experienced able man of to-day, to the thought of other able men of, say, seventy years ago, when arrangements were being made, under Albert the Good, for the great exhibition of 1851, from which bold enterprise emerged the idea of promoting Britain's productivity by means of a State-controlled system of instruction in "pure and applied science."

This is not the place to discuss the slowly penetrating but incalculably fruitful influence of the Science and Art Department, "the people's university," as Huxley had it, which began to take shape at that time, and which, in the intervening years has been fostered and made wonderfully efficient, despite occasional changes in the management, by successive groups of earnest scientists working wholeheartedly for the nation in the direction Sir William Whitla now advocates. This advocacy loses none of its importance, however slowly the progress of real reform has proceeded in the past and however hesitatingly response has come to the clear notes sounded by the great educationists Milton, Locke, Rousseau and others. On the contrary, we feel that the circumstances of the hour with its sharply-defined anticipations of the future give to Professor Whitla's words a force compelling their acceptance and application. Moreover, it is not in the mode of the political platform or from an academic chair that Sir William Whitla gives his exhortation. Nor is it as the "man in the street" who has just come to discern that well-organised science training is related to national prosperity and is, more or less in a helpless way, wondering what is to be done, that Sir William speaks. In jubilant tones he is able to say that the governors and the principal of the college have set their house in order, that a new era in secondary education in Ireland has begun and that Belfast leads the way. "They had no fewer than six fully-equipped laboratories manned by a full staff of experts," he announces, and he adds, "their workshop and engineering equipment should excite the envy of every high school in Britain." Be that as it may, this remarkable development testifies convincingly to change, amounting almost to revolution, in the public idea of the function of a secondary school. It is true "science" has been taught in schools, but passing beyond the teaching of science as an attractive time-table item in the curriculum of the "modern side," or as a serviceable artifice for grant-earning purposes, we find "scientific and practical courses designed to prepare and equip highly-trained recruits for commissions in the industrial army." Admirable, far-reaching and possible. Now and henceforth the nation will, as a rule, look to the secondary schools for a steady supply of able youths, strong in mind and body and trained practically in the basic principles of the industries on which its prosperity depends.

Nearly four years ago, Mr. J. W. Kempster, in a presidential address to the Belfast Association of Engineers,* expressed the hope that the discontinuity between school and shop life would be bridged and that the seeming incompatibility of the two ideas would vanish. His forecast and desire are in a fair way to realisation, and the reproach which men of affairs levelled against pedagogues and stereotyped educational officialism is fading away into "gratified surprise." The time was, not ages ago, when lack of skill not merely with "vulgar" fractions and the elusive dots, but in arithmetical operations generally, was the shibboleth of the public school product, and "practical" education was anathema save when, in Whewell's sense of "doing," it was made to apply particularly to construing and composition. For the education of a gentleman the classics, the playing fields and the school comradeship sufficed. Nor did they prove futile in the days when personal fortitude and lofty ideals saved the state.

For the control of the industries of to-day more is needed. Those who direct great enterprises and the *personnel* of the various departments, however considerate, however sympathetic, or even altruistic, they may be, must possess, if our production is to secure Britain's position as a manufacturing nation, high scientific knowledge and a clear comprehension of business, and be able to apply them to the problems of management and markets. There is no longer room for the *roi fainéant*. Virile, earnest, educated young men are wanted first of all for subordinate posts of responsibility. They are to approach their work armed with a personally-acquired knowledge of principles, modest in face of the achievements of the past, but acutely observant, trained to reflect and formulate, and ever eager to consider how improvements may be effected. Sound scientific training should add spring to their imagination while providing safeguards against unbalanced and haphazard endeavour. Time will try these young men, and from their ranks will emerge in due course those whose personality and capacity justify promotion to higher positions in industrial organisation.

Selective processes will be in operation all the way. In the secondary schools only those with aptitudes and strong predilections are to be enrolled as "cadets of the industrial army." Evidences

* See ENGINEERING, vol. c., p. 595.

of suitability for commissions will declare themselves during the probationary period, and so from step to step aptitude, tenacity and worth will determine progress. We are not disposed to say that the prospect in this outlook is much, if at all, in contrast to what now prevails. But we gladly welcome a general adoption of the scheme outlined in the official report as containing the promise of a much needed supply of capable youths carefully selected, rigorously yet liberally trained in the essential things of science and business, and with those qualities of mind that make for success in industries.

Had the scheme advocated by Dr. Whitla pressed exclusively or even preponderatingly a purely science curriculum for those secondary school senior boys whose minds turned towards engineering or shipbuilding, or any of the various industries, chemical and mechanical, which have made Belfast prosperous, we would have counselled caution. This is unnecessary, for we find that in co-operation with the educative work in the chemical and physical laboratories and in the engineering shops and drawing office the time-honoured humanistic studies will play their part in the building up of men of character and skill. "The duties, the struggles and the responsibilities of life" have to be met with the bold heart and disciplined will. The individual must not be merged in the machine. Perfect law is not incompatible with liberty of spirit and well ordered habits of thought reached by systematic training are not obstacles to intellectual activity of the higher order. Holding these views we are glad that with the awakening there has been no forgetting of those vital elements in the education of the latter-day sons of the land of saints and scholars. Summing up his arguments, the Principal believes, and we are with him in that belief, that the two types of culture —the humanistic and the technical—can flourish side by side. "In the corporate activities which will link them together, as well as in the English and the mathematical classes, which they will share on equal terms, the Grecian and the technologist will discard any antagonism and discover the community of interests, ideals and obligations which unites workers in the multifarious branches of human endeavour." There is no Prussian regimentation here, but a broad inspiring conception of the function of a secondary school.

THE ROYAL SOCIETY SOIRÉE.

THE second soirée of the Royal Society, the first Ladies' Night after the war, held at Burlington House on Wednesday last, following the first soirée within the customary interval of four weeks. The number of scientific novelties shown for the first time is generally not large on these occasions, some of the exhibits of the first soirée being frequently brought up once more, in response to request. As regards the exhibits of this class we shall have to refer our readers to our issue of May 30, page 709; as apparatus not noticed previously, especially some collective exhibits, will claim all the space at our disposal.

Only one group of astronomical exhibits, those shown by the Rev. A. L. Cortie, S.J., of Stonyhurst, was novel in this sense. Father Cortie showed red pencil drawings of sun spots and faculæ, made during this May and June, some illustrating the transit of the sun's disc by a fine group of spots (May 13 to 24); the spot and faculæ near the eastern limb of the sun on May 30 were almost coincident with the limb at the time of the total solar eclipse on May 29. The other exhibit, progressive spectra of Nova Aquilæ, 1918, represented sixfold enlargements of the original negatives and strikingly exemplified the gradual change of the type of spectrum that this star underwent. The dark-line spectrum of June 10–11 had, by June 15, changed into a bright band spectrum of the a Cygni type and had passed by July 29 into the γ Orionis type. On the first photograph (June 10–11) the doubling and strong displacement of the dark hydrogen line were notable, while in the spectra of the last four weeks the strengthening of the nebular bands was the striking feature.

Dr. A. O. Rankine, of University College, W.C., demonstrated his novel apparatus for the Transmission of Speech by Light, which he described before the Physical Society on May 9 last. His transmitter was mounted at the one end of the flight of large rooms, his receiver at the other end. The transmitter is a combination of a diaphragm and mirror device which causes the intensity of an arc lamp beam or of the sun rays to fluctuate in accordance with the vibrations of speech. Part of this beam is concentrated by means of a lens on a selenium cell in the receiver, the cell being in series with a telephone which the listener applies to his ear. Transmission of speech has by these means been effected over distances of more than 1 mile. The interposition of a screen entirely cuts off the sound. The rooms of the Royal Society were not very favourable ground for these experiments. In the Physical Society the other day the two parts of the apparatus were mounted at the end of a long passage, and it was then quite clear that the selenium cell responded to the sound vibrations before the direct sound waves reached the listener. We reserve our detailed description of this very interesting apparatus.

The other great experiment of the evening was the demonstration of Directional Wireless Telegraphy by Mr. A. A. Campbell Swinton, F.R.S. To make the effects audible to large audiences Mr. Campbell Swinton had arranged a number of apparatus on a table. But the remarkable thing which he demonstrated is that he could, without any aerial, and merely with the aid of a flat wire coil, some valve amplifiers, two variable condensers and two batteries, overhear signals sent from Paris as well as from Poldhu, and that his apparatus, when responding to Paris, would not simultaneously respond to Poldhu, because the one happens to lie south of London and the other west. That sufficient energy could be picked up in the building was due to the use of thermoionic vacuum-tube amplifiers. Those used by Mr. Swinton are of French make and differ, not in construction (filament and grid, surrounded by a cylinder), but in arrangement from the ordinary British form. Six of these amplifiers were arranged in series, separated by small transformers; each valve (as tested by the National Physical Laboratory) magnifies the radio-energy received 18 times, the six instruments in series hence increase the energy 18^6 times; the first three of the group magnify the radio frequency, the last three the audio-frequency. The coil consisted of copper wire, wound in a vertical plane in 30 turns round a hexagonal frame which to receive from Paris was placed with its plane in the direction Paris–London. When the frame was turned about its vertical axis the sounds became indistinct and faint, and by turning the frame the two directions of maximum intensity, north and south—in which the magnetic waves at right angles to the wave propagation may be assumed to cross the plane of the coil—could easily be determined. The Brown relays, and the loud-speaking telephone, as well as the siphon recorder, also on the table, were only added to facilitate the demonstration. The demonstration was quite successful though much disturbed by the atmospheric disturbances of the day.

The new form of kinematograph of Mr. A. Mallock, F.R.S., is also a novelty. In this instrument the film (with the small photographs on it) is wound like a belt over the circumference of a wheel which resembles a commutator, the segments of which are replaced by mirror strips. The virtual images of all the film pictures are at the wheel axis and being stationary can hence be projected on the screen (on which they are seen) by a fixed lens. The film is illuminated from the side through a mirror placed at a distance from the film equal to the radius of the wheel. The screen remains continuously illuminated, therefore, and the successive pictures replace one another without dark intervals and without perceptible flickers, no matter at what rate the wheel is turned. The working model exhibited looks very promising.

Many exhibits were connected with Aircraft. Captain Hamshaw Thomas, R.A.F., displayed a large number of photographs illustrating the physical geography of Palestine, all taken during the campaign, from heights of 14,000 ft. maximum with exposure of 0·03 second, for the purpose of correcting the maps of about 2,000 sq. miles of the country, mostly barren rocky ground. The erosion of the mountains, the peculiar ridges of the Wadis, and the valley and course of the River Jordan, down to its joining the Dead Sea in a valley finally 1,200 ft. below sea level, are remarkable features of these photographs, each 6½ in. by 8½ in., representing about 1¼ miles by 2 miles of country. Some captured German maps, of the same type, enlarged, seemed to have lost decidedly in definition by the enlargement.

The Director of Research, Air Ministry, by permission of which Captain Thomas showed his photographs, also had two other exhibits, a Course-setting bomb sight, essentially a light, simple mechanical instrument, and a German Periscopic bomb sight, a heavy telescope with rotatable prisms. The former Wimperis instrument which was fitted to machines operating overland and—slightly modified—used also for anti-submarine work at sea, comprises a graduated horizontal bar, in which another bar, the wind bar, slides; the latter is linked to the small compass; the observer looks through two rings sliding up and down a vertical tube on which they are adjusted to the altitude of the aeroplane. The ring sights and bead sights can be set according to this altitude, the air-speed of the craft and the speed and direction of the wind. The whole instrument, which also serves for determining the speed and direction of the wind, as well as for aerial navigation by dead reckoning, fits into a portable box.

On behalf of the Royal Aircraft Establishment, Farnborough, Messrs. Dobson, Smith and Keeley demonstrated the use of a group of eight standard and research aeronautical instruments. The first was the compass designed by the late Captain Keith Lucas, F.R.S., to minimise the errors occurring when flying in a northerly course because the terrestrial magnetic field tends to dip the needle. It is a long-period compass, and there is an attachment by the aid of which the navigator when flying, say 10 deg. east by north, sets a pointer to this direction and is then able to follow the pointer. The R.A.E. accelerometer records the variation of apparent gravity on an aeroplane by photographing on a kinematograph film the movements of a fine glass fibre bent into a horizontal bow; the fibre is illuminated by a lamp, and another glass fibre records the air-speed on the same film; the whole instrument is encased in one small box. The R.A.E. kymograph is a laboratory instrument recording the movement of the craft in roll, pitch or yaw by photographing the image of the sun on a moving film. The R.A.E. pressure-plotting apparatus records the pressure or suction over an aeroplane wing by means of small pipes which open flush with the surface and lead to a multiple-pressure gauge. This gauge consists of a number of U-tubes, 34 on the instrument shown; the 34 tubes form elements of a semi-cylinder, about 1 ft. in height, each constituting one limb of the U, the other wider limb being common to all the tubes; the mercury or liquid in the U-tubes give 34 parallel vertical lines on a photographic film. The R.A.E. climbmeter indicates the rate at which an aeroplane is rising or falling; there is a vacuum flask with a small leak, and the difference in pressure, shown in a U-tube, is proportional to the rate of climbing; the whole instrument, like the others, fits into a small case and weighs only a few ounces. The records from kites and kite balloons, are obtained in the shape of small-size photographs, taken on moving films, of the dials of instruments showing the height, temperature and wind velocity and direction. For the latter observation pin points are attached to the compass needle which will keep sufficiently steady during the short exposure. In the R.A.E. bubble-sextant a bubble (floating in a curved tube) and a star observed are brought to coincidence by the observer with the aid of a prism; on the shaking aeroplane the bubble is not steady, of course, but it always remains in the focus of a lens. The R.A.E. petrol flow meter, finally, is a small box-shaped instrument; the petrol enters the cylindrical box through the controlling tap and moves a vane inside. Most of these handy and light instruments were made in the Aircraft Establishment.

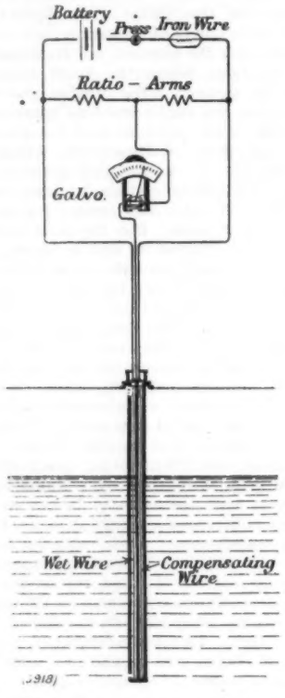
The other aeronautical instruments to be mentioned concern the oxygen supply. The

apparatus worked out by Professor G. Dreyer, of Oxford, in conjunction with Lieutenant G. F. Hanson and Major H. F. Pierce, United States Army, was used extensively during the latter part of the war for supplying flying men with the amount of oxygen their altitude required. The essential parts are a hand-set valve, a series of aneroids working on a piston which controls the flow, and a special reducing valve which is not affected by changes in the external pressure and temperature; for this purpose the valve embodies a small air chamber, confined between a corrugated metal diaphragm and the screwed-down lid of the valve. The simple apparatus of the same inventors for the investigation of the effects of low oxygen pressure on aeronauts is a recording meter for the laboratory, built up of glass tubes, metal valves and rubber tubing, through which mixtures of two gases, nitrogen and oxygen, can be passed at widely varying rates of flow and in different proportions, so as to imitate air at different heights; the meter is not in itself so simple, but it is easily manipulated, and it replaces the very heavy "depression" chambers in which such tests are otherwise conducted. The apparatus made for the continuous administration of oxygen by Mr. J. Barcroft, F.R.S., and by Dr. J. S. Haldane, F.R.S., and Dr. J. G. Priestley, were mentioned in connection with the previous soirée a month ago.

From the National Physical Laboratory came the Three-electrode Vacuum Tubes for producing Oscillations of Telephone Frequency which Mr. F. E. Smith, F.R.S., exhibited last time; the Radium Luminous Dial Testing Apparatus of Mr. J. W. T. Walsh, which has since 1915 served for testing more than 50,000 radium-painted dials, and which we have described on another occasion and shall again notice; and a new liquid level indicator.

The distant-reading Liquid-Level Indicator, exhibited by Mr. E. A. Griffiths, until recently a member of the staff of the National Physical Laboratory, now of the Air Board, is a clever, simple instrument (patented) of the telemeter type. which enables the engineer to ascertain the level of the petrol in his tank and of the water in his boiler or conduit, &c., simply by pressing a button on an apparatus which looks like a small-size galvanometer. The pointer of this instrument then moves up to 20. *e.g.*, which means that he has 20 in. of petrol in his tank. The instrument is a Wheatstone bridge, and the principle is that the heat loss from a wire is greater when the wire is in a liquid than when exposed to air or vapour. As our diagram shows, two wires are stretched within brass tubes; the one tube is closed below, the other is perforated at its lower end so that it is washed by the liquid; the whole is mounted in a tube which is lowered into the tank; in this respect the instrument resembles a pyrometer. The wires are made of platinum or nickel, and they form two arms of a bridge. When the current of a battery of a few volts flows through the wires, the wire immersed in the petrol will cool more rapidly than the other, and the resistance-ratio will indicate the depth of liquid to which the wire is immersed. The atmospheric temperature may also vary; the second wire will compensate for this influence. An iron ballast resistance maintains a constant current in the bridge circuit which is thus rendered independent of variations in the battery voltage. This device is analogous to that of the Nernst lamp, and has the additional advantage of reducing the temperature coefficient of the instrument to negligible proportions, since the volt/ampere curve of iron wire ballast is practically constant for the range 2 volts to 5 volts at about 1 ampere, which Mr. Griffiths' battery does not exceed. All the parts, except the tube to be lowered into the tank, and the battery, that is, the bridge, the iron resistance, the pointer and the push button, are combined in the small galvanometer case mentioned, which thus completes the outfit. A robust type of moving coil instrument is used; yet it is possible to obtain ample sensitivity with a temperature elevation in the wire of less than 20 deg. C. and a current of $\frac{1}{2}$ ampere. In the demonstration the petrol was admitted into a high glass cylinder to adjustable depths; the pointer at once indicated the correct depth. One point should be mentioned to meet the objection that may be raised that the exposure of petrol vapours to hot wires might cause inflammation and explosion. Mr. Griffiths has found that currents, eight times as strong as those he uses, would make his wires glow, but would not give rise to inflammation because the cooling of the confined small space is too rapid. He was impressed with this fact while testing magnetos when sparking contacts may be splashed with liquid; explosions were not set up by these mishaps.

Of the remaining exhibits, mostly of biological and pathological character, we can only mention the demonstration, by Dr. Leonard Hill, F.R.S., of the stunting of plants in windy places (mustard seeds growing in a draught-channel) which may be



due to the drying, cooling and mechanical action of the wind; the instructive exhibits of Sir Almroth Wright, F.R.S., and Messrs. L. Colebrook and A. Fleming, illustrating Nature's Methods for the Destruction of Microbes in Wounds and the parts played by the white blood corpuscles and the blood fluids; and the always attractive collection of sea animals and fishes and their food shown on behalf of the Marine Biological Association of Plymouth, by Dr. J. E. Allen, F.R.S., Mrs. E. W. Sexton and Dr. Marie Lebour. The latter exhibits also exemplified a curious case of Mendelism studied by Dr. Allen and Mrs. Sexton. The eye of a small shrimp, *gammarus chevreuxi*, normally shows a chalk-white pigment dotted with a more deep-seated black pigment; sometimes the spots are red or absent (albino). When a red-eyed *gammarus* and an albino are crossed, the first generation has normal black-dotted eyes; in the second generation all variations occur, numerically according to the Mendelian law, and sometimes a colourless eye is observed, devoid of any pigment; this last peculiarity is associated with irregularity of shape.

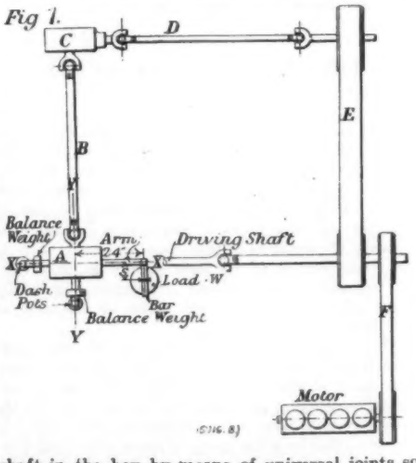
THE NATIONAL PHYSICAL LABORATORY.

THE annual inspection of the National Physical Laboratory by the General Board once more brought, on Tuesday afternoon last, a large number of visitors to Bushy Park, where they were received by Sir J. J. Thomson, O.M., who, as president of the Royal Society, remains chairman of the Board. Yet it was not as it had been before the war. The annual meetings had been suspended during the war, and those who had not had any opportunity of visiting the Laboratory since the summer of 1914, were deeply impressed with the growth of the National Institution. Building operations had been going on when the war broke out; more buildings, houses of several storeys as well as temporary huts, are still rising, and the overcrowding of most of the departments testifies to the necessity of the expansions. The reception was held in one of the large new houses, in which a 14-ft. wind channel is nearing completion, and the new buildings near the entrance are more and more transforming the old rustic grounds into a crowded settlement. Another sign of the changes made was the absence of the annual Report which used to be presented at these meetings. The Report will in future come out in the winter, and deal with the work of the calendar year. This change was, in fact, already effected last winter; the Report being essentially of a confidential character, however, has not yet been circulated. Under these conditions we shall have to wait till the end of the year for the general and detailed information on the work done, in progress and projected, on the equipment and staff, and on the finances. Visitors were enabled, however, last Tuesday, not only to see the numerous demonstrations prepared by the director, Sir R. T. Glazebrook, C.B., F.R.S., and the staff, in order to exemplify recent advances, but also to examine everything so far as the time at disposal permitted. The official veil has not been lifted yet; but there was a great deal to learn.

Engineering Department.—In the Engineering Department, apart from the Aeronautical Department, the return to normal conditions will be easier than in some others, though special war work has, of course, fallen to this department as well. Dr. T. E. Stanton, F.R.S., the superintendent of the two combined departments, retains his chief assistants, Messrs. C. Jakeman, R. G. C. Batson, J. H. Hyde, A. Bailey, and G. A. Hankins, with Messrs. E. F. Relf, A. B. Pannell, A. Fage and others in the Aerodynamical Department.

The worm-gear testing machine devised by Mr. F. W. Lanchester attracted much attention. In this machine, which is illustrated diagrammatically in Fig. 1, the gear-box is so mounted on ball bearings as to have freedom of motion about two axes at right angles to one another, the axis of the driving shaft X X and the axis of the driven shaft Y Y. The two axes are connected to the worm wheel and

Fig 1.



shaft in the box by means of universal joints so arranged that any turning moment about either axis is eliminated when the box is balanced by a weight. These balance weights are marked in the diagram. An arm is further attached to the box in the direction of X X, but the weight W (marked load in the diagram) is carried by an arm, at right angles to X X and hence parallel to Y Y, and 24 in. therefrom. The box is first balanced in both directions, and the torque on the driving shaft is obtained by noting the load lifted at the 24 in. radius. The torque on the driven shaft is then balanced by sliding the weight along the arm until, at distance S, the torque is balanced about X X. When the two torques are equal their ratio would give the gear ratio if there were no friction. To overcome friction, the load W has to be shifted to S_1; then S/S_1 will be the efficiency. If S were

6 in., and S_1 should be 6·67 in., *e.g.*, that would mean a loss of 10 per cent. in the efficiency. During the first tests of the Lanchester gearing, which Mr. C. Jakeman conducted on behalf of the Laboratory at the Daimler Works, Coventry, the speed varied between 400 revolutions and 1540 revolutions, and the efficiency kept between 93 per cent. and 97 per cent., the average value being 95 or 96. The results were probably correct to 0·2 per cent., and the accuracy is very satisfactory for practical purposes.

The diagram, Fig. 1, illustrates another noteworthy point of Mr. Lanchester's ingenious arrangement. The drive is taken from the driven shaft B to a bevel gearing C and the shaft D, parallel to X X, and from a pulley E on D back to a pulley on X X through a belt. By altering the tension on this belt the pressure between the worm and wheel, and therefore the torque, can be adjusted to any desired value, while the driving belt and motor have to supply only the mechanical losses of power in the apparatus. The whole machine described is now utilised for two purposes, for gear testing and for lubricant testing. The gear-box takes about 2 pints of oil. To test an oil, the box is emptied and cleaned and refilled with the oil which is afterwards also examined for traces of metal from the worm gearing; but the comparison is based upon the efficiency test.

In these tests the pressures go up to values which make the ordinary data on the changes in the viscosity of an oil with pressure quite useless. On viscosity changes with high pressures, up to 3,000 atmospheres, there was only the work of O. Faust, of Göttingen, 1912, who dealt mainly with alcohol, ether and carbon disulphide. Hence Dr. Stanton took up the investigation of the viscosity at high pressures, and Mr. J. H. Hyde designed an apparatus on the method suggested by Dr. Stanton. The apparatus consists essentially of a system of two horizontal and two vertical tubes, joined to form a rectangle and a closed circuit of liquid under pressure. The upper horizontal tube is of capillary dimensions; the two vertical tubes are bored and ground truly cylindrical within 2 parts in 10,000, and truly parallel; the lower half of the circuit contain mercury, the upper the liquid under test. One end of the system rests on a horizontal knife-edge; the other end is connected to a horizontal lever through a vertical link. The lever is pivoted at one end and provided at the other with a pointer moving over a finely-divided scale; the lever is supported from a fixed beam above by a spiral spring. The apparatus—except the glass capillary itself which is mounted within the upper tube by means of a stuffing-box—is built in steel. When the mercury is displaced by a given amount, flow will take place round the circuit owing to the difference of head, and if the spring be so designed that its rate of extension be equal to the rate of change of head of the mercury, the flow of the liquid under test will occur under a constant pressure difference and at a velocity which can be calculated from the rate of extension of the spring. The initial displacement of the mercury is obtained by tilting the rectangle, and the amount of the displacement is determined from the scale reading and the dimensions of the mechanism. The flow is regulated by means of a valve which does not communicate with the air, of course; additional pressure (up to 11 tons so far) is put on the liquid by means of a pump or other devices. The oil to be tested is forced through the capillary and also through the annular space around it; the internal and external pressures on the glass are hence equal, and the glass is not subject to a bursting pressure. The motion of the pointer over the scale is observed through a telescope, and the tests are so conducted that the pointer sinks through a space of 1 cm. in about 20 minutes. The whole apparatus is lowered into an oil bath, the temperature of which can be maintained for long periods within 0·05 deg. C.; the temperature of the oil in the tubes is controlled by a thermocouple. The ends of the spiral spring are made adjustable along the length of both the lever and the beam above, so that the same spring, of known stiffness, can be used in testing many liquids. The length of the capillary is 50 cm.; the diameters of the capillaries range up to 1·5 mm., 0·75 mm. is the average, and finer bores are used for testing water. The whole research is conducted for the Lubrication Committee, and results will be submitted to this committee in the first instance. The value of the viscosity is calculated from the formula: $\eta/\rho = \pi h \rho r^4 t/8 v l$, where η is the coefficient of viscosity of a liquid of density ρ, h the head of liquid (mercury head), s and l are radius and length of the capillary, and v is the volume of oil flowing in time t. Of these quantities r and l are determined directly, h is fixed by the initial tilt given to the system, and v and t are deduced from the rate of fall of the pointer and the diameter of the vertical tube. The density ρ has separately to be determined for different pressures.

Wear of Cables and Ropes.—The apparatus for testing the wear of stranded cables and ropes makes use of Dr. Stanton's alternating stress machine. A reciprocating horizontal motion is imparted to a framing. The specimen is wound, in one convolution, round a pulley which takes part in this reciprocating motion, at the rate of 800 reversals per minute, and is thus horizontally displaced through 4 in. at each reversal. The one end of the specimen, about 2 ft. in length, is joined to the machine by a wire, the other end is loaded; the machine pulls the test-piece to and fro' on its pulley and exposes it to alternating stresses, to which it will sooner or later succumb. In the case of stranded wires, graded pulleys up to 8 in. in diameter are used; in the case of manila hemp tape, also shown last Tuesday, the pulley diameter was 2½ in., and the load applied was one-tenth of the breaking load; this load would be too heavy for wire cables. The machine, on which four specimens can be tested simultaneously, is run continuously for days, and the test is continued for 1,000,000 reversals if the specimen should bear that. The oil splashed about by the machine is kept off the specimen by a screen.

Extensometer Tests at High Temperature.—The extensometer tests at high temperature (Mr. A. G. Hankins) are novel in two respects, we believe. Extensometers had not previously been applied to the hot specimen while on the tensile-strength machine, and the Martens mirror extensometers used were made in the Laboratory itself. The specimen is tested while surrounded by an electric-resistance furnace, 15·5 in. high, heated up to 500 deg. C. (so far), and with the extensometer bars clamped to it. Two pairs of extensometer bars are used; the knife-edges of the first outer pair rest against the upper end of the test length of 2 in.; those of the second inner pair against the lower end. The knife-edges are held tight by spring clips fastened with their eyes over studs on the edges; half-way down the bars are encircled by a calliper clip. The two mirrors are inserted between the lower ends of the two pairs, and a roller is attached to the inside of each inner bar, so that the inner bars glide on the specimen. When the specimen stretches, the mirrors turn as they are mounted on diamond-shaped pieces of steel, and from their angular deflections the elongation is estimated. A micrometer screw bears against the lower end of the outer bars for making adjustments.

Fatigue and Wear Tests.—The tests for the determination of fatigue resistance are also made at high temperatures but now so far only on light alloys. The Wöhler machine used is horizontally arranged, and the furnace surrounding the specimen is so wound, as in the case just mentioned, that the uniform zone of high temperature is in the middle portion, ¾ in. in length, in which fracture may be expected to take place. The apparatus for the measurement of journal friction and for wear-testing belong to the type of abrasion machines of Dr. Stanton and Mr. Batson. In the simplest form of the machine the journal or a ring of the material is placed between three rollers, each capable of independent rotation; the upper roller is loaded and its axis can move in the vertical direction. In practice this machine did not prove satisfactory, as it is very difficult to prevent slipping, and a Wöhler machine was hence adapted to the abrasion test of Mr. Saniter. The specimen is fixed in a chuck revolving at high speed and carrying a hardened steel ring, the internal diameter of which is larger than the external diameter of the specimen; a load is attached to the ring. As we stated in our previous reports these tests are apt to roll the abraded metal into the specimens and to increase the surface hardness of the specimen while under rolling friction, and it appeared doubtful whether the results would be applicable both to cases of wear due to high pressure and very small relative motion, and to wear with relatively small pressure but large relative movement. The abrading ring was therefore connected to the chuck by means of an Oldham coupling so that ring and specimens describe a revolution in the same direction in the same time, the line of contact remaining fixed relatively to the machine. The slip of the ring (diameter D) over the specimen (diameter d) would then be $(D - d)\pi$ per revolution. In the wear-testing machine for hardened gauges, the diameters are, *e.g.*, ⅝ in. and ⅝ in.; the machine is run at 2,000 revolutions for 20 minutes, and the depth of the abrasion is subsequently determined by the aid of the micrometer. It is customary to express the wear per 1,000 ft. slip. The slips are deduced from the speeds, not automatically recorded. An air blast is directed into the slot between the ring and the specimen to remove the abraded particles as well as to cool the parts.

For fatigue testing with alternating torsion the Laboratory further makes use of two types of machines, the one a Stromeyer machine, the other worked out in the Laboratory. In the latter Stanton machine the horizontal shaft, turned by an electric motor at 2,000 r.p.m. and more, ends in a fork at right angles to the shaft; across this fork is fixed the test-piece, which is thus also at right angles to the axis of rotation, and the bar to which the load is attached enters the middle of the test-piece in a taper and is in alignment with the axis of rotation; this bar is made thin so as to accommodate itself to the torsional deflections of the specimen.

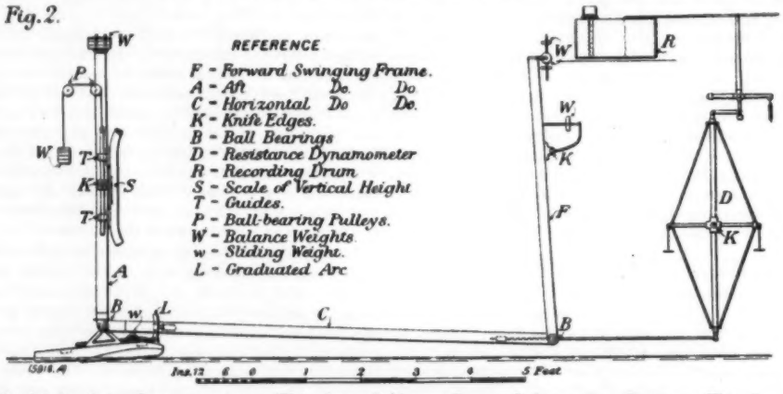
Impact Tests.—For the further elucidation of the interpretation and correlation of the results of different testing methods, tensile, hardness and impact tests, Dr. Stanton has devised a new type of pendulum-hammer machine. In this machine, which is built up of tubular steel, both the anvil and the tup move, the one being lifted to the right, the other to the left; the two pendulums are simultaneously released, and the striking velocity is thus raised to 40 ft., nearly twice as high as the speeds formerly used. In order to equalise the weights of the two pendulums the anvil is made of aluminium; it has the form of a U, through which the tup passes. Both the pendulums have the same radius, 4 ft. 6 in.; and the drop is 8 ft. The results of the experiments by Dr. Stanton and Mr. Batson are not yet published. In addition to the older impact machines of this type (two large ones, two smaller ones) some Izod machines have been installed for comparative testing; they are simple pendulum hammers, and the test-piece is fixed in a slot in the base of the instrument so as to project into the path of the pendulum.

Aerodynamics.—The 3-ft. channel, in the engineering laboratory, was occupied with the determination of rotary derivatives on a model of an airship of the Sea Scout type. These derivatives are required for stability calculations by Bryan's method; and the method of obtaining them experimentally was given in the 1912-13 Report of the Advisory Committee. The particular derivative being determined was the variation in lateral force due to yawing, and it is obtained by giving the model a forced oscillation in yaw while allowing it to swing freely as a pendulum in a lateral direction. By studying the motion of a spot of light on a screen outside the channel the value of the derivative can be obtained. The phenomenon of "spinning" of an aeroplane was demonstrated in the new 4-ft. channel by the auto-rotation of a model aeroplane. The model was mounted with its longitudinal axis somewhat inclined to the wind, in such a manner that it was free to rotate about an axis parallel with the wind. When rotation was started, in either direction, the rotation continued steadily as long as the wind was maintained, although the ailerons were in the normal mid position. The explanation is that the rotation increases the apparent angle of incidence of one-half of the wing and decreases that of the other, so that the former part is "stalled." The difference in lift produces a rolling moment which exactly balances

the friction torque in the model experiment. In the case of an aeroplane spinning freely, the speed of rotation will increase until the rolling moment becomes zero, when the motion will be quite stable. Any decrease in rate of spin will set up a rolling moment tending to increase the rate and *vice versa*.

In the No. 1 7-ft. channel experiments on the fall of head in air passing through the propeller of an airship in flight were being conducted. The upper part of the channel was occupied with a model airship of the R. 23 type, with the car in place. By pitôt tube readings taken in front and behind the propeller, rotating at a suitable speed, the fall of head can be determined, and in this way it will be possible to ascertain the cause of the discrepancy found between the thrust obtained on the airship and that calculated from the engine tests. The work of balancing an airship rudder was in hand in the No. 2 7-ft. channel. The rudder was in its correct position on a large airship model about 15 ft. in length, weighing, we were informed, about 130 lb. Moments would be measured about the rudder post with different balancing areas, and the latter would be varied until satisfactory values for the moments, over the whole range of movement, were obtained. In this room the roof balance for the third 7-ft. channel was on view. This channel, which is situated in the new buildings, is now practically completed, but the new 14-ft. by 7-ft. channel will, apparently, not be ready for work for several months yet. We also noticed in the No. 2 7-ft. channel room a new method, which has been suggested for mooring airships in the open. It consists of three wire ropes, which meet in a point on the airship, and pass over three snatch blocks arranged on the ground at the angles of a large equilateral triangle. The three ends of the ropes are led inwards from the snatch blocks to three of the angles of a quadrilateral figure formed of wire ropes, and the other angle of this quadrilateral is attached to a fixed point on the ground. This arrangement acts as a compensating device, and serves to keep the ropes taut while allowing a certain amount of movement of the airship. We understand that the whole scheme will shortly be given a trial on a practical scale, and that it is intended more for use as a temporary station, which can be quickly and cheaply set up in almost any position, than for permanent installation in one place.

Fig. 2.



The William Froude National Tank.—The staff of the Tank Department under Mr. G. S. Baker, superintendent, has increased to seven members. Matters are returning to normal conditions, fortunately, as a great deal of research work will have to be resumed. One of the problems under investigation is the proper arrangement of the bilge keels. The demonstrations of last Tuesday illustrated a very important line of investigations, tests of seaplane floats on the travelling truck; in the first set of experiments a float was planing on the water while being towed by the truck, in the second the impact was determined when a seaplane alighted on the water from the truck.

Experiments on float designs were commenced in the Tank Department in June, 1912, by Mr. Baker and Mr. G. H. Millar, and were later, when Captain Millar had joined the Forces—he was first imprisoned and finally killed in a seaplane accident—continued in conjunction with Miss Keary. The first endeavours were confined to single-float type of machines; the floats built to Tank design were tested in 1914 and proved extremely efficient, being able to get off the water with three-quarters full power instead of full power with the original floats. Experiments in the swell of the Isle of Wight paddle steamers were also satisfactory. As regards the developments, a distinction is made between flying boats, fitted with one float, and boat planes or seaplanes fitted with two floats; the former appear to be far more seaworthy. Flying boats were first tested in 1913; the earlier types all porpoised badly (i.e., they had a kind of leaping motion on the water) at certain speeds, whilst the good model will not do more than rise or fall (sit back); the work was hence concentrated on improving resistance and stability. The obvious advantages of narrow beam experiments on transverse stability (1915) showed that considerable negative metacentric height could be accepted without detriment. The final form obtained in these tests was followed in the design of various boats which can bear rough usage. The general arrangements of the experiments shown, by Mr. Baker on resistance, running angle and longitudinal stability of floats when planing on the water, will be understood from the diagram, Fig. 2. The vertical elevation of the boat and its slope are indicated by an enlarging arm, and its speed and resistance are recorded by the dynamometer D on the revolving drum R. The diagram does not show the balancing frame, as now used, which is put on the top of the boat. The balancing aims at bringing the centre of gravity of the model in line with the pivot so that the float when towed rocks about its own centre of gravity; this is effected by means of weights placed on the top of the balancing frame. The towing point itself can be raised or lowered with respect to the pivot, and the long towing rod is the only restraint on the model. Ordinary tests are conducted in smooth water; to test the behaviour of a craft in a bad choppy sea, men stir the Tank water up by means of booms creating waves several inches in height. The models used in the experiments were of the two-step type; the fore part is curved and joins the body of the boat in a step, and there is a second small step further aft. A great variety of boat models could be seen, showing the variations the shapes have undergone.

The other experiments illustrated a very important problem now under investigation. With aeroplanes of high speeds and heavy weights the question of landing is becoming increasingly difficult, and that applies with equal force to commercial seaplanes which will probably have to carry heavy weights and might smash themselves when "landing" on water. That landing may be level (pancaking) or at a slope. In the demonstrations the model was dropped from the truck while moving at uniform speed; the fall was always vertical, but the slope could be varied. The tests measure the deceleration and the blow received by the float; the striking boat will first be retarded in its motion, to rebound immediately afterwards. To effect measurements within this very short period, Mr. Baker has adopted the following arrangement. The falling boat drags with it a paper tape which rests on a horizontal frame; above the paper is a pen vibrating in synchronism with a tuning fork at 150 oscillations per second. On the tape dots are hence marked corresponding to intervals of 1/150 second; from the spacings of these dots curves of the spaces traversed and hence of the deceleration and subsequent acceleration are deduced. Together with the boat there is also dropped a small weight, which in falling turns a screw; this screw traverses the pen across the tape. The records are about 2 ft. long, and Mr. Baker has already obtained some 300 of these records, with flat-bottom and V-shaped boats of various shapes. The actual drop allowed for the model does not exceed 2 in. or 3 in.

(To be continued.)

LITERATURE.

The Naval Annual, 1919. Edited by Earl BRASSEY, D.C.L., A.I.N.A., and JOHN LEYLAND. London: William Clowes and Sons, Limited, 31, Haymarket, S.W. 1. [Price 21s. net.]

THE "Naval Annual" this year is doubly welcome, not only because of the reputation of its predecessors, but because it gives us full and accurate information of the naval events during the past two or three years and full data as to the particulars of warships, and, indeed, of all existing guns and other munitions of war. It is three years since the last edition appeared, but that edition suffered from the necessity for a large measure of secrecy regarding the work being done. Moreover, in the intervening years, when the lessons of naval tactics were being analysed and applied, greater advances were made than in any corresponding period in the history of naval science. Thus the narratives in the successive chapters dealing with the different phases of naval activity are full of interest. Earl Brassey is to be congratulated not only on the choice of writers, but on the division of the work amongst those writers, and therefore on the scope of the treatment.

In the issues of the Annual published during the war a notable feature was the chronological narrative of the naval events and incidents in the world war, and we are glad that Commander C. N. Robinson, R.N., has continued this narrative, because we have in these chapters in successive volumes a concise yet all-embracing record of naval operations, not only in the main terrain of the war, but in the Baltic, the Mediterranean, the Adriatic, the Black Sea, and in connection with commercial raiding and the capture of the German Colonies, terminating with the internment, on November 21 last, of the German High Seas Fleet, which has now been so ignominiously sunk in Scapa Flow. A similar narrative in connection with the operation of the navies of our Allies—France, Italy, Japan and the United States—are included. These are from the pens of officers of the respective navies, and presumably have been written with the full authority of the admiralties of these countries.

Mr. John Leyland contributes the third chapter, which deals with the enemy navy. He has made a special study of German naval affairs and of German psychology, and his contribution here has as much to do with the latter as with the former. He points out that all the evidence which came to light after the armistice was signed showed that the officers had been ready to strike a blow, and were even eager to fight, but that the spirit of discouragement and mutiny had sunk so deeply into the minds of the men that they were powerless to overcome it. There was a rooted division in the German Fleet. The aristocratic officers who had crowded the quarter deck looked with ill-veiled contempt upon the officers of the engineering branch, and the resulting situation was dangerous to the fleet. The artificer class brought in the spirit of the big towns and the discontents of the workshop. Volunteering for submarine service had come to an end, and the men were driven to this duty as to any other. Great numbers of them never returned, and there was bitter discontent in the barracks and depots, while the parents deprived of their sons and the widows and orphans made loud laments in the ports. But Mr. Leyland is not unmindful also of the watchfulness of the British Fleet. The Germans were watched up to the very edge, and in the intricacies

of their own minefields. The sea sense, deepened in many weeks of cruising in storm, fog, peril and watchfulness, the steady discipline and unshaken nerve of the British Fleet were against them, and thus, as Captain Persius pointed out in the German papers, the German seamen of the lower deck had been at last brought, by bad handling, to a state of despair. The surrender of the German Fleet was thus a recognition of the inevitable.

Lord Brassey himself gives comparative tables of the various fleets as they stand to-day, but obviously these can scarcely be of the same interest and importance as prior to the war, particularly in view of the surrender and, now, the sinking of the German ships.

Mr. Alexander Richardson, as in former Annuals, contributes a chapter dealing with warship-propelling machinery, and in this issue devotes himself to war developments. He shows that movement has been along extensions of well proved lines. It is a case not so much of innovation as of the application on a great scale of principles and mechanism which had been introduced tentatively, if not experimentally, in the years immediately preceding the war. Engineer Vice-Admiral Henry J. Oram, as Engineer-in-Chief of the Fleet, and the Deputy Engineer-in-Chief, and successor from June, 1917, Engineer Vice-Admiral Sir George Goodwin, showed together great enterprise; and thus when the call was made for higher powers, in order to obtain the great speeds demanded by the naval tactician, it became possible to achieve, with mighty ships, all that was desired without undue risks and in association with a higher degree of efficiency. The author points out that battle cruisers for Britain, Japan and the United States are now building, having powers ranging up to 180,000 shaft horse-power, with speeds up to 33 knots, while in the case of destroyers the power ranges up to 40,000 shaft horse-power and the speeds to 39·6 knots. In the case of submarine boats, steam-driven vessels have attained 24 knots and oil-driven vessels 18 knots on the surface; when submerged our vessels have attained speeds of 15 knots. All these results far exceed those attained by the ships of any other nation. The author proceeds to show how the improvements necessary to attain these results were effected without undue weight and with high efficiency. He indicates how the weight of machinery has been steadily decreased, and we may put in brief tabular form the salient results he gives under this heading:—

Weight of Machinery (lbs. per Horse Power).

—	1894.	1914.	1919.
	lb.	lb.	lb.
Battleships	242	174	110*
Battle cruisers	194	113*	50*
Destroyers	50	35*	30*

* Burning oil.

The reason for introducing helical gearing between the turbine and the propeller is clearly enunciated and facts are given regarding applications. Two torpedo-boat destroyers, with partly-geared turbines, had been in commission from August, 1912, one of two all-geared torpedo-boat destroyers on order had completed exhaustive trials before the war, a cruiser with geared turbines was ordered early in 1914, and since then gearing has become universal in warships. The larger ships are driven by four screws, but in the destroyers and some light cruisers two propellers only are used. Just prior to the adoption of all-geared turbines for destroyers the three-shaft direct-driven arrangement of turbines with geared cruising turbines on two shafts was fitted. The estimated steam consumption for the turbines only for the three-shaft direct-driven arrangement with geared cruising turbines, was about 12 lb. per shaft horse-power at full power, 15 lb. at one-fifth and 16 lb. at one-tenth of full power. In the latest destroyers single-reduction gearing is fitted, and the estimated steam consumption for the turbines only is about 10·7 lb. per shaft horse-power at full power, 12·5 lb. at one-fifth and 15 lb. at one-tenth of full power. The consumptions are based on a vacuum of 27 in. at full power. The change-over from an arrangement of three-shaft direct-driven turbines to two-shaft all-geared turbines permitted an increase in the propeller efficiency of about 12 per cent. and an additional improvement in the steam consumption of the turbines only, of about 10 per cent. at full power. There is about 2 per cent. saving in the total weight of machinery. In the light cruiser class single-reduction gearing is fitted, and the estimated steam consumption for the turbines only is about 11 lb. per shaft horse-power at full power, 12·8 lb. at one-fifth and 13 lb. at one-tenth of full power. Battle cruisers with single-reduction geared turbines are designed for about 9·9 lb. steam consumption per shaft horse-power at full power, 12·5 at one-fifth and 12·5 at one-tenth of full power. We tabulate the particulars for different installations, showing the steam consumption for turbines only and for all purposes:—

—	Steam—Lb. per S.H.P.		
	Full Power.	One-fifth Full Power.	One-tenth Full Power.
Destroyers.			
3-Shaft.—Direct-driven arrangement with geared cruising turbine.			
Turbines only	12·0	15·0	16·0
All purposes with auxiliary exhaust to turbines	13·0	16·75	18·5
2-Shaft.—Latest arrangement with all geared turbines.			
Turbines only	10·7	12·5	15·0
All purposes with auxiliary exhaust to turbines	11·7	14·25	17·5
Light Cruisers.			
2 and 4-Shaft.—All geared turbine arrangement with cruising turbines.			
Turbines only	11·0	12·8	13·0
All purposes with auxiliary exhaust to turbines	12·0	14·8	16·0
Battle Cruisers.			
4-Shaft.—All geared turbine arrangement with cruising turbines.			
Turbines only	9·9	12·5	12·5
All purposes with auxiliary exhaust to turbines	11·15	15·0	16·5

The question of the utilisation of electricity between the turbines and the propeller is very fully dealt with, and it is shown that the British Admiralty have not been at all oblivious of the possibilities of the system, but on the other hand are adopting a policy of experiment. As has already been shown in ENGINEERING the "K" submarines have electric motors on the shafts between the turbines and the propellers, and from this experience will be gained. The results of the trials of the United States battleship New Mexico, which is fitted with electric transmission gear, are analysed. The interesting point is that the installation is said to weigh about 2,350 tons, working out at an equivalent of 170 lb. per shaft horse-power developed on the full-power trial; whereas the machinery of approximately corresponding power in our warships works out at 140 lb. per shaft horse-power, representing a difference of about 400 tons against the New Mexico machinery. Nor is any gain in steam consumption established except at low powers. The remainder of the engineering chapter in the Annual is taken up with the narration of interesting experiments made with details in connection with turbine machinery, and with a review of the progress made in oil engines. It is pointed out that in our Diesel engines for submarines the consumption of oil per brake horse-power is about 0·4 lb. per hour, and as low as 0·381 lb. has been attained.

Further chapters deal with the submarine war on merchant ships, on the convoy system, on Admiralty administration and naval *personnel* on naval education, naval pay and welfare conditions, and on naval aircraft. In connection with the last it is pointed out that the war has shown us that the flying boat and seaplane are essential elements of the Navy. They must develop *pari passu* with the big airship, though in practice their work may not always be the same. The airship can rarely be other than an air cruiser for scouting work, of the utmost value in suitable weather. The flying machine can fly in a wind, when necessary, which would prove disastrous for an airship. It can travel at higher speed and can carry reconnaissance beyond the range of the airship, although the latter has greater endurance and may remain longer away from her base. Many difficulties which attended air navigation have been overcome. The controlling conditions are studied and known. Suitable flying days are recognised. For scouting about the British Isles and the North Sea they number about half the days in the year for craft heavier than air. The difficulty of providing engines, which was a real one earlier in the war, has now almost disappeared.

Captain Robinson, in the chapter on "Construction in War Time," reviews the work done during the war, obviously following the lines of Sir Eustace d'Eyncourt's paper, which has already been published in ENGINEERING (page 482 *ante*).

The part of the Annual dealing with ordnance and armour has this year been contributed by Mr. Richardson, and there is given a description, with illustrations, of a great variety of new weapons of naval warfare. It is shown that the 18-in. gun was the largest adopted. This weapon was originally fitted to the cruiser Furious, and, upon her being adapted as an aeroplane carrier, the guns were fitted in monitors and the gun mountings used in these monitors are described. It is interesting to note that the projectiles used by these guns weighed about 1½ tons, and their capabilities, worked out under the du Marre formula, showed that at point-blank range no less than 41 in. of hard-faced armour could be perforated; this is equivalent to a wall of unhardened steel of about 54 in. At 10 miles and 20 miles a projectile from this gun would perforate, respectively, 22 in. and 12½ in. of hard-faced armour of the latest and best type. Finally, at the extreme range of 30 miles the shell would still perforate armour of ordinary steel plate having a thickness of close upon a foot. In actual practice the projectile perforated a hard-faced plate for a thickness nearly equal to its calibre when fired at a velocity equivalent to a range of about 14 miles. An interesting feature has reference to gun-mountings constructed at Elswick, where all the operations of the turret and gun are manipulated by one lever, no directions being necessary, as the movements of the lever round a rectangular fitting controls the valves actuating each successive movement in the correct sequence of operations. Thus "directions" are unnecessary. At the same time it is impossible to actuate any valve out of its order. Gun sights, mountings for high-angle fire, modifications in breach mechanism, bomb-throwing mechanism, gun direction and other features are fully dealt with, and we are glad to note a very decided acknowledgment of the indebtedness of the nation to the large armament firms, without whose effort it would have been impossible to have won the war.

"Brassey's Naval Annual" is recognised as a great book of reference, and this year for the first time since the war we have correct particulars of all ships of all powers, elevations and plans of the principal types of ships of all navies, tables of ballistics of the guns of all countries and makers, and, finally, reprints of all official documents connected with naval operations, so that this year's publication attains to the high standard of the earlier volumes, and proves, further, that Lord Brassey to-day is maintaining the high repute for accuracy and completeness which was won by his father.

BOOKS RECEIVED.

Smithsonian Institution, United States National Museum. Bulletin 102. *Natural Gas: Its Production, Service and Conservation.* By SAMUEL S. WYER. Washington: Government Printing Office.

United States Bureau of Mines. Bulletin 160. *Rock Quarrying for Cement Manufacture.* By OLIVER BOWLES. Washington: Government Printing Office. [Price 25 cents.]

The Fire at the Quaker Oats Company's Premises at Peterboro', Ontario, Canada, on December 11, 1916, being two Reports. Part I by A. J. MYLREA and Part II by T. D. MYLREA. London: The British Fire Prevention Committee, 8, Waterloo-place, S.W. 1. [Price 4s.]

Memorandum on the Industrial Situation after the War. The Garton Foundation. Revised and enlarged edition, January, 1919. London: Harrison and Sons. [Price 2s. net.]

The Science of Labour and its Organisation. By Dr. JOSEPH IOTEYKO. London: George Routledge and Sons, Limited. [Price 3s. 6d. net.]

INDUSTRIAL NOTES.

FOUR reports of the Coal Commission, which concluded its sittings on Saturday, the 14th inst., have been issued as a Parliamentary paper.

The one by Mr. Justice Sankey, the chairman, recommends that Parliament be invited immediately to pass legislation acquiring the coal royalties for the State and paying fair and just compensation to the owners. It recommends, further, that the scheme for local administration which it sets out, or any modification of it adopted by Parliament, be immediately set up with the aid of the Coal Controller's Department, and that Parliament be invited to pass legislation acquiring the coal mines for the State, after the scheme has been worked for three years from the date of the report, paying fair and just compensation to the owners. The chairman believes that the workers at present employed can and will maintain an output of 250,000,000 tons a year at least, which was the figure adopted in the interim report of March 20 last presented by him and his three colleagues. The chairman then details his scheme which is dealt with in our leading article.

The Labour Members' report is signed by Sir Leo C. Money, Messrs. R. Smillie, F. Hodges, H. Smith, R. H. Tawney and Sidney Webb. They announce that they are in substantial agreement with the chairman's report, and think it unnecessary to set forth any separate statement of their views. They wish, however, to emphasise several points, as follow:—

They suggest that, with a view to securing the cordial co-operation of the workers in the success of the industry, it is necessary to provide for a fuller representation of the workers on the District and National Councils, on the lines indicated in the scheme submitted by Mr. W. Straker.

Whilst fully recognising the necessity of working rules, and the importance of preventing unnecessary stoppages, they feel that the provisions of some of the paragraphs in the chairman's report may be used to impose upon the workers by law a particular form of contract, without their consent—an innovation to which they think it will be difficult to gain agreement, and which they believe to be not the best calculated to attain the object.

They are of opinion that all coke and by-product plant attached to collieries should be treated as part of the coal mines and should be acquired by the State with the coal mines.

They think it important that whatever payment is made to the owners pending the general acquisition of the mines should not be computed upon the tonnage gotten.

Whilst recognising, with regret, that the output from the mines has not yet satisfactorily recovered from the adverse circumstances which have depressed it during the war, they wish to emphasise the fact that no evidence has been produced to show that the men are refraining from doing their best. They believe that this is not the case, and that other causes are at work. The miners demand an immediate inquiry, and they support this demand. During the period that must necessarily elapse before the institution of the machinery for the administration of the mines proposed by the chairman, they think it is of the utmost public importance that there should be no deficiency of tubs, no lack of wagons, no shortage of materials and no obstacle to prompt clearance from pithead, all of which are reported now to exist.

Three among the signatories (Messrs. F. Hodges, R. Smillie and Herbert Smith) do not agree that any compensation whatever should be paid to the present mineral owners for the mineral rights to be acquired by the State. But this must not be taken to imply that there would be objection to the grant of compassionate allowances in cases in which small royalty owners are expropriated in such a way as to deprive them of their means of livelihood.

The coalowners' report is signed by Mr. A. Balfour, Mr. R. W. Cooper, Sir A. Nimmo, Sir A. M. Smith and Mr. E. Williams. Among their statements, we abstract the following:

They think it is only right that the community should realise the extent to which success has attended the efforts of private enterprise in the coal industry, and they specially refer to the following extract from Lord Gainford's evidence before the Commission:—

"Coalowners have not been slow to risk their capital in the development of coal, and have taken risks which the State never could have undertaken, wherever there appeared to be any possible expectation of success. The development in output during the past thirty years prior to the war, from 128,000,000 tons to 288,000,000 tons, and an increase in the men employed from 492,422 to 1,118,452, is eloquent testimony to the enterprise, initiative and skill which coalowners and their managers have brought to bear upon the industry. So far from necessary development having been retarded in the hands of the present owners all available evidence shows that the full quantity of coal required from time to time by the nation has always been forthcoming and an export trade has been steadily built up. (N.B.—16,000,000 tons in 1873 to 82,000,000 tons in 1913.)"

They add that they have carefully weighed the whole of the evidence and have come to the conclusion that the nationalisation of the coal industry in any form would be detrimental to the development of the industry and to the economic life of the country.

It is clear that the present economic position of the coal industry cannot continue.

Wages in any industry can only continue to be paid to the extent that the industry can bear.

It is economically unsound to pay wages either: (*a*) By repayment, in the form of a wage subsidy, of taxes previously collected from an industry, or (*b*) by subsidies from moneys collected from the taxpayer.

If the coal industry is to be resumed on an economic basis it is inevitable that one of two things must happen: (*a*) There must be a large increase in the output of coal and a decrease in the cost of production, or (*b*) the price of coal to the consumer must be increased and the consequences of this increase upon other industries and on the community generally must be faced.

Without expressing any opinion on the subject, they feel very strongly that in view of the statements made before the Commission the causes which have contributed to the fall in output should be the subject of immediate and complete investigation.

They also feel strongly that no action which will vitally affect the nation as a whole or will result in granting preferential treatment to any section of the community should be taken without first referring the question to the community.

They refute the statements made at the sittings as to safety and other points. They recommend that a Mines Department be set up to exercise the functions of State so far as regards the ownership of coal; that Pit Committees, District Councils and a National Council be established, the latter formed of representatives of mine owners and mine workers, appointed by the districts, for dealing with any question of national interest which might be referred to it.

It should be a condition of any vesting of coal in the State that the existing owners of royalties receive fair and just compensation, and that the owners and occupiers of the surface be protected by suitable conditions and restrictions imposed upon the State.

The coal should only vest in the State subject to the existing leases or tenancies, and in any case where an existing lease or tenancy is held for a term of years of which less than sixty are unexpired, the lessees or tenants should have the option of requiring the term to be extended upon reasonable conditions as to rent and otherwise up to the full term of sixty years.

As regards those cases where the coal is being worked by the owner as colliery owner it should only vest in the State subject to the granting to him of a lease for such a number of years not exceeding sixty years, as he may require upon such conditions as to rent or otherwise as may be customary in the district, fair and just compensation being paid to him.

The report by Sir A. Duckham says, among other points, that the working of over 3,000 collieries by more than 1,500 separate interests has resulted in heavy losses of coal, inefficient working, and unnecessary difficulties in the winning of the coal. The present serious decrease in the output of coal is caused partly by the general state of disturbance in industry, owing to the change-over from war to peace conditions, and partly by a general slackening of effort on the part of all workers. Higher remuneration to labour has not resulted in larger output. It has not been shown that there is an increased output per worker or less industrial strife when undertakings are owned and controlled by the State for the benefit of the community. The development of the coal industry (the chief source of wealth and industrial success of this country), has been entirely due to private enterprise. On the other hand, grave losses to the community have been caused by lack of co-ordination in the efforts of private enterprise. National ownership and control of collieries does not offer a real solution of the problems. Many advantages have been claimed for nationalisation; practically none has been sustained. Many cogent objections have been advanced against nationalisation, the majority of which have not been refuted. The nationalisation of the coal-mining industry would be an unprecedented and colossal experiment. A mistake would result in a national calamity. Sir A. Duckham then recommends that the whole of the mineral rights of Great Britain should be acquired by the State, the value of such rights being estimated in each case on the same basis as adopted by the Inland Revenue in assessing ownership of minerals for death duties, due regard being given to the change in value of money owing to the war, increased taxation, &c. A Ministry of Mines should be set up, which should at a later date, form one of a group of Ministries attached to a Ministry of Industry. The duties of the Ministry of Mines should be (*inter alia*): (*a*) To supervise and control all mineral rights throughout Great Britain, and to ensure the proper working of all minerals; (*b*) to ensure the making of a complete geological survey (including the systematic proving of all coal areas) of the whole country; (*c*) to be responsible, through its inspectors, for the proper equipment and running of mines to ensure safety; (*d*) to initiate and, if necessary, carry out research for the improvement in the conditions of those working in and about mines, better methods of winning coal, &c.; (*e*) to undertake the study of the special diseases of underground workers, and to initiate special treatment; (*f*) to exercise any control of the industry which a national emergency may render necessary; (*g*) to advise the Minister of Labour as to the special conditions present in the coal industry; (*h*) to co-operate with any Government Department set up for the conservation of fuel.

His report then deals with the setting up of area commissions, the appointment of different representatives, and stated that the wages of all workpeople and employees should be guaranteed by minimum or standard rates. An equitable system of payment on increased output and efficiency should be arranged and made applicable, as far as possible, to all manual workers, in addition to the system of piece-work rates at present in force.

A dispute in the cotton trade in regard to work and wages which had been proceeding for several months past terminated last Monday by a strike immediately followed by a settlement. Notices to cease work were handed in on Saturday, the 21st inst.; the strike began on Monday, and both parties came to terms on the same day. The following official statement was issued last Monday dealing with the matter:—

On the suggestion of the Cotton Reconstruction Board an arrangement was made for a conference to be held at the Victoria Hotel, Manchester, between the representatives of the Federation of Master Cotton Spinners' Manufacturers' Association, the Amalgamated Cotton Spinners' Manufacturers Association and the United Textile Factory Workers' Association, under the chairmanship of Sir A. H. Dixon. After lengthy negotiations, it was unanimously agreed to recommend the following for acceptance by the various organisations referred to: (1) A 48-hours working week, times of starting and stopping to be mutually arranged by this joint committee; (2) an advance of 30 per cent. on the standard piece price list rate of wages; (3) an equivalent alteration in rates of pay in the case of those workpeople whose wages are not governed by a standard piece price list; (4) the altered hours of work and rates of pay shall come into operation when work is resumed; (5) to remain in operation without change for a period of eighteen months from the date of this coming into operation, and after the expiration of that period one month's notice to be given by either side of any desired alteration. This was signed by representatives of the three parties concerned.

It was further agreed that the mills should be open for the resumption of work on Monday next.

Another conference between the representatives of the employers and operatives' organisations was held on Wednesday last for the purpose of discussing the question of allocating the times of starting and stopping during the new working week of 48 hours.

BOY ARTIFICERS IN THE ROYAL NAVY.—The London County Council has been authorised by the Admiralty to nominate a number of boys for entry in January, 1920, as boy artificers in the Royal Navy, and the Council is accordingly prepared to consider applications for nominations. Candidates must be between the ages of 15 and 16 years on January 1, 1920, *i.e.*, their date of birth must fall either on January 2, 1904, or January 1, 1905, or *between* these dates. Candidates must be the sons of British-born parents. Application forms (T. 2/249) may be obtained from the Education Officer, London County Council Education Offices, Victoria Embankment, W.C., and must be returned not later than August 30, 1919.

EXPORTS TO SWEDEN.—The Board of Trade are officially informed that the Swedish Government have given a general guarantee which has been accepted by the Associated Governments, that goods imported into that country will not be re-exported to enemy destinations. They announce, therefore, that except for goods on Lists A or B, all restrictions on exports to Sweden, whether by freight or by parcel post have now been removed. It is no longer necessary to consign any goods to importing associations or to official consignees in that country. Applications for licences to export goods on Lists A or B should continue to be made to the Export Licence Department, at 1, Queen Anne's Gate Buildings, Westminster, S.W. 1.

THE PAST AND FUTURE OF LABOUR.

To the Editor of Engineering.

SIR,—On looking over the present industrial situation, one is forced to recognise the fact that this country is about to face the most critical stage which has thus far arisen in the whole of its history. No such transition from war conditions to peace conditions has ever occurred before. And if that were not enough to make the most sagacious and far-seeing employer stay awake at night, when he should be taking his well-earned rest, he finds that labour is also going through a transitional period, the results of which he cannot foresee, however vital. At present, the omens are not, to say the least, very favourable. The old simile of the blind giant awakening to his strength, holds good in this case, and so far, the disturbing factor seems to be that most of the people who are teaching the giant to use his strength are disciples of destruction.

The problem with which the employer has to deal, is this: how is he going to turn this immense force into a national asset, and at the same time make the giant realise that such employment of his force is to his own advantage. A careful analysis of the present situation brings one to three main causes.

I. Bad pre-war conditions.
II. Abnormal conditions for the past four years.
III. Suspicion on the part of the employee.

Of these three causes, the third is, in my opinion, the most important, and at the same time the least recognised. Even employers, who should know the working classes thoroughly, are at present seeking for a compromise between the first and second cause, without giving much thought to the third. And yet it is the third which is the all-powerful lever which forms the driving force of that dreadful doctrine which we know as Bolshevism. Where suspicion does not exist, and cannot be made to grow, there also Bolshevism cannot obtain a footing.

In order to arrive at a logical conclusion, I will take the first three cases enunciated above, and by a simple analysis try to find what conditions are required to nullify them, and so meet the requirements of both employer and employee to-day.

I. *Bad Pre-War Conditions.*—I do not think that any employer whose honest desire is to treat his men justly will deny that an overwhelmingly large proportion of labour, was, before the war, living under the worst possible conditions. Advancing civilisation brings many benefits in its train—it also brings added responsibilities. As more sources of wealth are opened, so should more benefits accrue to those who produce such added wealth. And if those responsibilities do not fall directly on those who open up this added wealth, on whom should they lie? The State? The State is composed of all the members thereof, and its responsibility is more that of supervision than of actual performance. One of the lessons I have learnt in the army is that good discipline implies self-discipline on the part of each individual along the lines directed by the supervising body, and involves a good deal of concerted thought by the people who are disciplined.

It cannot be denied by the most prejudiced supporters of capital, that employers in general, before the war, did not do all they could to fulfil these responsibilities. It was only when production had to be increased to an unprecedented extent, along totally new lines, that employers began to realise what had been left undone. I have known in pre-war days, of skilled men, such as foundry laborers living and struggling to bring up a family on the princely salary of 23*s.* a week in good times, which salary was reduced to 21*s.* a week in slack times. Many such instances might be cited, but they are too well known to require reiteration. Thus it will be seen that the first condition of our scheme is that it must offer a big improvement on pre-war conditions.

II. *Abnormal Condition for the past Four Years.*—This fact does not require any enlarging as regards employers. But what is not realised by the workers is that these conditions do not represent the normal wealth at the disposal of, or produced by British industry. They must be made to understand that, in common parlance, we have been patronising the pawnshop rather extensively since the autumn of 1914, and that it is time for us to begin redeeming our pledges. In my opinion the present rather stringent demands of the miners are the outcome of this mistaken idea. If the improvement needed is to be a lasting and healthy one, it must stand on its own two feet, and not have to be propped up and financed by further visits to the pawn-shop. Furthermore, the men must understand that all this vast and intensified production of the past four years has been entirely unremunerative as far as the State is concerned. We have been producing, not to sell, or to build wealth, but to destroy. Industrially speaking, all this work has been useless. It has been made to be destroyed. Only one thing can remain out of it all and that is the *bill*. Thus we come to the second condition of our scheme. Briefly it is this: It must be self-supporting.

III. *Suspicion.*—In this one word, we come to the very root of all our present labour troubles. Most people who are acquainted with men who employ any large number of employees, have heard of cases where the employer has honestly tried to benefit his men with no result. I have generally heard such results put down to ignorance on the part of the workers. "They refuse to be benefited—do not know what is good for them." True they need education. At present they are undoubtedly suffering from that little knowledge which is such a dangerous thing. But they cannot be made wise in a week. Before anything lasting and healthy can be put in, the terrible canker of suspicion must be cut out—and it is going to be a patient job. One single scheme which has for its apparent object the uplifting or bettering of the workers, but whose real object is to exploit them, can do more harm than a dozen honest attempts. And the British workman has been exploited in this way, not once, but many times. Truly, this suspicion is the worst evil with which the just employer has to contend, and getting rid of it must of necessity be a drastic procedure. One of the very finest things which the State could do would be to make such an example of the first employer who cloaked a swindling scheme under the title of a workers' advancement scheme, that no one would ever dare to attempt it again. For such acts destroy all mutual confidence between master and man and suck the very life blood of industry.

But it is impossible to look back for the last hundred years without seeing many such schemes. It is the result of those schemes which constitutes the terrible handicap which faces the employer to-day. Old traditions are an incalculable asset if they are good—they are correspondingly dangerous if they are bad. And the chief condition of any scheme of improvement to-day must be that it shall do away with suspicion.

As to the method of attaining this objective, it is no use burying one's head in the sand. The employee will have to know something of the financial end of the business. The more he knows of it, and the more thoroughly he knows it, the better. The average workman is a fair-minded man and always a sportsman, and he will readily understand that it is not going to be to his advantage to try to make capital out of his knowledge. On the contrary, in the writer's opinion, that knowledge will breed an interest and loyalty to his employer, which he never felt before. Of course he didn't feel it. He had nothing to be loyal about. One has only to try to step into his shoes and gauge his thoughts to find that this is true. It is of very little use going half-way. The employer must travel the whole road with him, to show him there are no ambushes. An employer may be the very essence of justice and try his hardest to help the workmen, but the workmen must be convinced of it. They have mostly been ambushed before.

Most of the schemes to which industrial unrest and the various motives of employers have so far given birth may be roughly classed under two heads. The first, one can only call purely benevolent schemes, and the second, co-partnership schemes. Under the first heading, come such schemes as the building of clubs, hospitals, cottages, founding of benevolent societies, insurance, &c. Under the second we have a fairly large variety of schemes for making the worker a participator in the profits of the concern on a share-holding basis. Of the two it would be difficult to say which is the better. Certainly the second is the more utilitarian, although more open to mixed motives on the part of the promulgator, and consequently viewed with the greatest suspicion by the employee. In order to carry success with it, such a scheme involves the giving of a large amount of information to the employee about the purely financial end of the concern. It is well not to shut one's eyes in this matter. The average shareholder does not put his money where he has not already pinned his faith. Moreover, he has to a certain extent, a fair amount of knowledge of the usual financial procedures. The workman, on the contrary, invests his labour wherever he can, and knows nothing of financial procedure, consequently in self defence, he has to use his only weapon, which is suspicion. The giving of such information is not always practicable, and a weak spot in the scheme is the result.

Before outlining my scheme, I think it but fair to myself to say that having been in the army for the past four years, and not having been in touch with things industrial, it is quite possible that such a scheme as I am about to outline, may have already been tried. If such be the case, I cannot claim acquaintance with it. In my case it is mainly an application of some of the things I have learnt about dealing with the average type of man in the army.

Three things are necessary to the success of any such scheme. They are as follows:—

A. Discipline.
B. Interest.
C. Loyalty.

The word discipline has been too well drummed into the British nation as a whole, to need much explanation here. Though, even now I do not think many realise to the full its tremendous power. It is so often misconstrued. For its definition one cannot improve on the words of a very fine soldier, under whom I had the honour to serve—"The sinking of the individual for the good of the whole." How many realise its full import? The employer talks of discipline. Is *he* willing to sink his individuality for the general good? Discipline, to be perfect, touches the highest as well as the lowest, and it brings in the vital principle of team work. Much has been said in the past about competition—what a fine thing it is and what splendid results accrue from it. Very true. Competition *is* a fine thing, but like other fine things it can be overdone. It is a good servant but a bad master. It can go to a certain limit and be the perfect servant that it should be. One step farther and it begins to assume the mastery. Then—good-bye to that other magnificent servant called co-operation. It is possible to get two departments competing until they are completely at loggerheads with each other, and any manager knows what that means. So I am going to ask you to lay a little less stress on competition and a little more on co-operation. A judicious blending of the two will work wonders.

B. *Interest.*—Every manager or employer will know how difficult it is to get men to take a thorough interest in their work, and (more important still) in the firm's work generally. Let us suppose that every manager were to ask himself the following question, seriously and honestly, "What have my men got to interest them during the hours they spend in my works?" What would the answer be? In attempting to get at such an answer, let us take a case in point. Supposing Mr. Thoughtful Manager we put you in the place of one of your workmen. Supposing also for the sake of example, that you have adopted what I believe are known as "Efficiency" methods. Take the case of a machine operator turning out shall we say, crank-webs of standard sizes. Could you yourself find enough interest in planing crank-webs day after day, week after week, to keep your interest fixed? I venture to think not. And if you could, your interest and general outlook would become, to put it mildly, rather narrowed. And if, with your better mentality, you could not do such a thing, why expect your workmen to do it? Even prospects of higher pay and bonuses for more and better work cannot produce the right kind of interest. If your interest were centred solely on higher pay you would not be giving your best. Your imagination needs something wider and higher to work on than your cheque at the end of the quarter. Then why not give your men something of your broad outlook? The most optimistic mind would hardly say that labour is suffering from too wide a vision.

C. *Loyalty.*—At present loyalty seems to be a rather absent quality in most works and factories. The reason is not far to seek. Loyalty in order to exist, must first of all be watered and fed. Nearly all men have it latent in them. Certainly the average British workman is plentifully endowed with it. The question is how to bring it out, and make it expand. The average skilled mechanic, or the average labourer is not a man of high imaginative qualities. We have already seen that his training and daily work is not of the kind which makes for broadness of vision. What he needs in physical food is something solid and substantial that he can get his teeth into. Similarly, his mental food must be concrete, something he can get hold of and around which the roots of that latent loyalty can cling.

For the purpose of illustrating my scheme, I have taken the produce which is perhaps the most familiar to me—marine engines. From a managerial standpoint, I know nothing about them. But I have perhaps enough knowledge of their manufacture to enable me to apply my scheme to them on broad lines. For the filling of details, a more detailed technical knowledge would be required than that which I possess.

I will take then, the case of a factory which builds marine engines. Its production before the war was of the average. During the war, of course, it has been keyed up to the top notch, but since the war is over, much of the direct incentive which produced such good results has gone. Its employees are suspicious of a return to old conditions, and are ready to make trouble at any sign of a change.

We will suppose this factory has, let us say, twelve engines ready for erection. It gets all its erecting staff together, and divides it, say, into four gangs. In each of these four gangs is represented every trade necessary for the erecting of an engine (not very many, to be sure mainly fitters and erectors). Each gang elects two representatives, one of whom will act as the treasurer of the gang. These representatives convene, together with the representatives of the employer, and each gang is given a contract to erect three engines. The arrival at a fair contract price is a thing which will require careful study, and in working towards it, the employer must work towards the abolishing of that deadly suspicion already spoken of.

Doubtless a good accountant could reduce all the factors in the making of the price to a set of plainly put figures which the gang representatives could understand. The salient point is that they *must* understand, and be thoroughly convinced that the price is a fair one, and that they are not being ambushed. The weak point of co-partnership schemes on a shareholder basis is the difficulty of presenting this information. And at the best of times, it is always possible to juggle with shares. But a contract price is something concrete which the workers can grasp and the difficulty of supplying the necessary information, is in my opinion, greatly minimised.

The contracts having been made, the workers go ahead to erect the engines. When they have finished they receive the contract price. What they do with it then is of no business to the employer. The following suggestion may, however, be of value. Suppose that each man in the gang is paid at trade union rates for the time he has worked on the erection of the three engines. Then if there is a surplus it could be taken and divided equally amongst the gang without reference to trades or rates of pay. Thus everyone would benefit equally for his industry and proportionately for his skill.

Having gone thus far, I will ask you to go a little farther and widen your focus. Suppose with the erecting shop plan as a precedent, we form a gang of men which includes every trade necessary to *create* a marine engine. Starting with patternmakers, go on to moulders, fettlers, machinists, turners, brassfounders, coppersmiths, forgemen, platers, fitters and erectors, crane-men labourers, and every other necessary trade. It looks rather startling, doesn't it? And yet the more one looks at it and thinks of it, the less startling it appears. For if one analyses the whole thing, one finds that its keynote is simplicity. The working out of all the necessary details will, of course, present difficulties mainly owning to lack of precedent, but these difficulties would certainly not be insuperable.

The building of such a big gang, would certainly require a good deal of study and experiment in order to get the correct proportion of each trade. At the same time, it seems possible that, if a set of figures were worked out, showing the number of completed engines turned out in a certain time, the number of workmen of each trade employed on them, and the number of hours

worked on them by each trade, the result would be fairly good foundation for the forming of an experimental gang. Such an experiment could be tried, with a guarantee of trade union wages to each man concerned. And even if the scheme failed, the experiment might prove valuable as affording statistics gained in actual practice for any other such scheme which might be attempted.

It seems probable that such a scheme would entail the formation of small gangs, in certain trades, for the carrying out of what might be termed "stock-work," such as the building of standard patterns which could be used by more than one gang; the making and repairing of tools used by the gangs, and so forth. Such items would also affect the contract price offered, as would also the cost of getting out drawings, keeping the necessary stores, and the cost of running the various branches of the general office. Such expenses, however, could be computed by a good accountant, by taking an average cost to each department on a certain number of engines sold, and this figure would also supply a definite standard of running expenses for each department.

One minor difficulty which occurs is that there would be certain men who could not be allotted to any one gang. Take the case of a crane-man. He would probably be working for two or three gangs. In providing for him, precaution would have to be taken to see that it would not be to his interest to favour any one gang. It might be feasible to form all the crane-men into a small gang, and contract with them for all engines built. This, of course, would also bring a small charge against the large gangs costs.

The question of representation of the gangs is a very important one. With such a large gang as the one outlined, facilities for the keeping of accounts would have to be provided for. This, however, will be dealt with in a later paragraph.

This representation could be divided into three stages. First, the general meeting of the gang, at which all members would be present. Then a meeting of trade representatives at which one representative of each trade (elected by gang members of his trade) would sit. Finally, the men elected by the trade representatives to meet the employer's representative. General meetings and trade representative meetings would be held outside of working hours, and there should be little difficulty in getting the men to understand that time spent talking during working hours would mean money out of pocket and orders lost to the firm, and consequently to themselves. But I am decidedly of the opinion that facilities should be provided to enable the men to meet and talk things over. They will do so in any case, and if they find the firm helping them in it, they will talk in the right way. Besides this, it will form another blow at suspicion. If they desired it, the men should also be given the benefit of the guidance of experts employed by the firm to help them in their deliberations.

As regards the financial end of the contract, the following methods sound a little Utopian, but on analysis, seems quite feasible. Supposing that each member of the gang is asked to fill in a card, stating in which bank he desires to have his money deposited. Then at the end of a contract, his share of the contract price could be deposited in the bank. This share would be drawn up by his own gang secretary, and published on a general statement at the end of each contract. This, of course, would have to be done by general consent (Truck Acts) and could only be done after the scheme had been working for some time, and after due preparation. This latter part of the scheme could hardly be thought of for a long time, but it would not do any harm to work a long way ahead. By thus working, all preparations could be made to carry it into effect as soon as the gangs wished to adopt such a system of payment. *Then*, the employee would be at such a stage that good straight information regarding the firm's shares (either ordinary, or a special worker's issue) would make him a voluntary, keen and interested shareholder of the firm, with the firm's interests at heart, and fully recognising the proper place for his own individuality as part of the whole.

And how does such a scheme help to develop the three qualities which we have seen to be necessary to combat our first three causes? On looking back we find that the qualities in question were—Discipline, Interest and Loyalty. Taking them in order, we will apply them and see how they fit.

Discipline.—It has already been stated that the best discipline is self-discipline. Does it not seem feasible that this self-discipline is the very life blood of such a scheme as has been so roughly outlined? A gang of men, no longer mere wage-earners, but a complete partnership for the purpose of building marine engines. In order to be successful, they must have discipline, and that discipline *must* come from within. The employee concerned can see that as well as anybody. The more work he does, the more money he gets, and the better the work he does the more work he gets to do. Under such circumstances, it will be easily seen that the tendency would be for the individual members of each gang to discipline themselves and each other. A foreman, would then become what he should be—a technical adviser to the workmen in his shop—without having to waste valuable time acting as a kind of policeman.

Interest.—As we have seen, the employee, under such a scheme, ceases to be a cog in the machinery at a wage of so much an hour, and becomes a contractor from the firm. This by itself widens his interest. To go back to a previous example, the machinist planing crank webs has been given something bigger to think about than the particular crank-web which he happens to be working on. He is a part of the firm. The firm's policy is his policy—it has direct effects on his profits. He can see far more distinctly than ever before, the direct result of bad work or slow work on his part or on the part of his partners. He has a more direct incentive, and he is going to see that not only he himself, but that every member of his particular partnership does his share of the work well, and without wasting time. If he finds a bad actor in his gang, he is going to either make him see the errors of his ways, or else replace him by a better man.

Loyalty.—Having been given this direct interest in his firm's doings, he will, *ipso facto*, have given a concrete foundation on to which his loyal instincts can fasten. He knows why he must be loyal. He knows something about the firm—its standing its policy. He can see clearly that anything which benefits the firm, benefits him *directly*. While this fact would hold true correspondingly in a share-holding scheme, the workman would never be sure of it. And so to revert to our principal idea, the employer of labour to-day must never forget this one thing: The destruction of suspicion is the first necessity towards success in dealing with labour. Destroy suspicion and you will have gone a long way towards creating such loyalty as you have never imagined.

I am, yours truly,

May 26, 1919. "X."

THE ACID HEARTH AND SLAG.*

By J. H. WHITELEY and A. F. HALLIMOND, M.A.
(Stockton-on-Tees).

THE present paper is a record of observations and experiments made upon the acid open-hearth process during the past few years. The first part consists chiefly of a description of the structure of slowly cooled acid slags and of the stability-relations of the minerals formed in them. This was a necessary preliminary to the study of the structure of the hearth itself, which forms the subject of Part II. Part III deals with the reactions which occur in the molten slag; it is for the most part independent of the earlier portion and might be read separately. The view is here advanced that an important part of the oxidation of the metalloids is due to the reduction of ferric oxide, which is continually being formed in the slag by the action of the furnace gases. The subject is somewhat controversial, and the authors hope that, though their conclusions may not be entirely in accordance with the views of other workers, the consideration of the reactions from this standpoint may stimulate investigation of the many difficult problems connected with the acid process.

PART I.

THE MICROSTRUCTURE AND MINERAL COMPOSITION OF ACID SLAGS.

Most of the acid open-hearth slags described in this paper consist principally of the three oxides FeO, MnO, and SiO_2; they are relatively free from other oxides, such as CaO and MgO, and their behaviour is essentially that of the ternary system FeO–MnO–SiO_2. The slags obtained in the acid processes, while not sufficiently varied for the complete description of this system, serve to define fairly closely the behaviour of the more siliceous melts.

A general discussion of the crystalline constitution of a great variety of slags was published in 1903 by J. H. L. Vogt in his classical work dealing with the application of the principles of physical chemistry to the silicate melts.* The majority of Vogt's slags contain important amounts of lime, alumina, or magnesia, and are therefore not of service in the study of the above system. A certain number, however, resemble in composition those here described and have therefore been included in Table I, where a summary is given of the analyses of all the slags of which the microstructures are described in the present paper.

Rate of Cooling.—In dealing with silicate melts the greatest importance attaches to the rate at which the sample is cooled; small samples which have cooled rapidly are most frequently glassy, and even if crystallisation has occurred the conditions may differ widely from those in which the phase rule can be applied. It is important, therefore, to choose for examination samples which have cooled at the slowest rate possible. In the present case samples were taken from slag-balls weighing from 6 tons to 8 tons, and which had been cooled in air in the usual way. Even here the microstructure shows evidence of a certain degree of supercooling; the cristobalite in particular is invariably dendritic, a structure which probably indicates that the melt was approaching a labile condition with respect to this substance at the time when it crystallised. These melts may be said, therefore, to be on the border-line beyond which more quickly cooled slags will show increasing deviation from the conditions represented in a "phase-rule" diagram of the usual kind. The effects of super-cooling on the microstructure have been discussed in detail by Vogt, who found that even in cases where the failure of a crystalline substance to appear (owing to super-cooling) gave rise to a deviation from the correct proportions required for the various silicates by the equilibrium diagram, yet the boundaries of the different areas could be ascertained with considerable precision by observing the order of separation of the minerals. The method has been frequently used by other workers on the silicate melts, and by it the diagram given in Fig. 1 has been constructed.

It has been remarked that the acid slags here described are essentially melts of the three oxides FeO, MnO, and SiO_2. In the triangular diagram (Fig. 1) the composition of each slag has been represented by a point the distance of which from any one of the three sides is proportional to the percentage of the oxide named at the corner opposite that side. Before the general character of the diagram is considered, it will be necessary to describe briefly the minerals present in the various slags examined and their microstructure. Besides the examination of thin sections by transmitted light according to the usual petrographical method, useful information can often be obtained from the appearance of polished sections under vertical illumination. The latter method has recently been employed by Dr. McCance is a study of the non-metallic inclusions in steel,† and is particularly useful in dealing with very fine structures, since the highest magnification can be employed without that loss of definition which occurs with transparent sections, owing to their thickness; the outline of crystals is that of a true plane section, a fact which renders their identification more easy.

TABLE I.

No.	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MnO.	CaO.	MgO.	TiO_2.	Total.	FeO / FeO + MnO	Minerals in Order of Crystallisation.
										Per Cent.	
1	51·2	0·95	1·14	32·91	10·3	1·6	0·44	0·62	99·16	76·1	Tridymite with cristobalite, fayalite, glass.
2	50·5	0·75	1·36	33·55	10·75	1·7	1·05	0·57	100·23	75·7	Cristobalite, fayalite, glass.
3	55·2	1·25	0·70	30·1	9·8	1·9	0·32	0·15	99·42	75·4	Cristobalite with tridymite, fayalite, glass.
4	49·5	2·15	1·13	29·3	14·05	1·8	1·22	0·72	99·87	67·6	Cristobalite with tridymite, rhodonite, glass.
5	49·6	1·90	0·57	27·8	13·4	5·1	0·94	0·64	99·95	67·4	Cristobalite, rhodonite, glass.
6	52·0	1·18	0·57	24·43	13·10	5·8	1·87	0·70	99·65	65·1	Cristobalite, rhodonite, glass.‡
7	45·2	1·8	0·40	33·2	12·5	4·6	1·6	0·26	99·56	72·6	Rhodonite, fayalite, glass. ‖
8	47·9	1·72	1·2	20·85	10·8	13·0	3·89	0·58	99·94	..	Metasilicate (p. 7), glass with metasilicate.
9	48·2	1·93	1·12	26·0	13·2	7·8	1·37	0·48	100·10	..	Cristobalite, metasilicate, fayalite, glass.
10	56·4	1·45	..	27·6	8·3	5·1	0·91	0·45	100·21	76·8	Cristobalite with tridymite, fayalite, glass.
11	58·1	..	..	23·5	8·4	6·7	0·86	..	..	73·8	Tridymite, rhodonite and cristobalite, glass.
					Minerals separated from the above Slags 6, 7 and 8.						
6a	47·0	trace	0·40	29·03	16·6	5·6	1·94	0·05	100·62	63·6	Iron-rhodonite. (Fe, Mn, Ca) O, SiO_2.
7a	..	..	..	35·0	14·5	..	..	..	..	70·7	Iron-rhodonite. (Fe, Mn, Ca O, SiO_2.
8a	47·4	0·15	2·7	15·95	12·95	15·1	5·26	0·10	99·61	..	Metasilicate (probably new) separated by roasting, which has increased the Fe_2O_3.
					Slags described by Vogt.						
57	53·9	1·71	..	19·93	21·69	1·86	..	..	99·09	47·8	"Rhodonite slag."
58	47·34	3·52	..	9·06	39·42	0·45	0·03	..	99·82	18·7	"Rhodonite slag."
59	45·61	2·58	..	27·93	17·07	2·41	4·65	..	100·25	62·1	Rhodonite, glass.
60a	44·72	2·45	..	28	25	1·89	..	..	..	52·7	Rhodonite, fayalite and rhodonite, glass.
60b	42·85	3·94	..	15·62	36·83	0·70	trace	..	99·96	29·7	Rhodonite, fayalite, glass.
61	41·23	2·29	..	22	37	1·19	trace	..	..	37·3	Fayalite, rhodonite, glass.

* Paper read before the Iron and Steel Institute on Friday, May 9, 1919.

* J. H. L. Vogt, "Die Silikatschmelzlosungen," 1903.

† Journal of the Iron and Steel Institute, 1918, No. I, p. 239-286.

though, on the other hand, very small fibres and grains appear only as minute points where they meet the surface and are liable to be overlooked.

MINERALS OCCURRING IN ACID SLAGS.

1. *Silica.**—Both the high temperature forms of this substance, namely tridymite and cristobalite, commonly occur in acid slags, and may often be seen together in one microsection. They are distinguished by means of a slight difference between their refractive indices, and can often also be identified by their very characteristic crystal habits; an account of the methods used has recently been given by Dr. H. H. Thomas,† and the minerals here described have been determined in this way.

(a) *Cristobalite.*—Even in the largest slag-balls the crystals are dendritic. They occur as skeletal octahedra or, more often, as plates which in section show a curious ladder-like structure, very characteristic of this mineral; these plates are formed through the extension of a crystal by dendritic growth in directions parallel with one of the octahedron faces, usually in the direction of the three edges (No. 21, page 855). The flat dendrites so produced become covered on either side by a thin continuous film of cristobalite which entraps the interstitial iron silicate of the dendrites. Both the octahedra and the dendritic form are seen in section (No. 14, page 855. No. 26, page 856, shows the hollow octahedra in parallel growth on a flat plate from a cavity in the centre of the same slag-ball.

(b) *Tridymite.*—At the temperature of freezing of these slags is the stable form of silica. It occurs as thin hexagonal plates, which appear as laths in the section (No. 1, page 854). This habit was very constant in all the slags examined, but in the sections of the furnace-hearth elongated crystals are found, while it may be remarked that in certain silica bricks heated at lower temperatures the predominant habit is an arrow-head twin.

At temperatures approaching the melting point of pure silica, cristobalite is the stable form.‡ This view has recently been questioned by Professor Le Chatelier,§ but is very strongly confirmed by the evidence here given, for it is found that in the surface layers of the silica bricks, the banks, and the hearth of the acid furnace the silica is present as cristobalite. As regards the banks, at least, there can be little doubt that the material for the most part is in the solid state, even at the temperature of the furnace.

In view of the close similarity between the physical constants of the two forms of silica, it is not surprising to find that they differ but little in stability with respect to the melt, and that both minerals frequently occur together in the same slag in proportions that vary quite irregularly from point to point in the section. As has been said, cristobalite is invariably skeletal, while the tridymite crystals exhibit a stable tabular habit. It seems clear that, on super-cooling, the unstable phase often crystallises first and undergoes rapid growth in the dendritic form. Crystals of tridymite, on the other hand, even when present in a super-cooled melt, seem to have a much slower rate of crystal growth than cristobalite, and are frequently to be seen scattered among cristobalite of subsequent growth.

2. *Silicates of the Olivine Group.*—The orthosilicate (monosilicate) of iron, $2FeO,SiO_2$, which crystallises in this group, is known as fayalite, while tephroite is the corresponding isomorphous manganese silicate. In dealing with such compounds as these, which can crystallise together in a more or less complete series of mixed crystals, the mineral names are generally used to denote also crystals that approximate in composition to the pure compounds. When both bases are present in nearly equal proportions, an ambiguity arises; this is the case with the present group, the iron-manganese olivines from the acid slags are sometimes richer in fayalite, sometimes in tephroite, and both names have been employed by previous writers. Vogt for brevity calls the mineral fayalite, and it will be convenient in the present paper to use this name to indicate all the iron-manganese olivines met with, as well as the pure iron compound.

A mineral containing equal amounts of the fayalite and tephroite molecules has been termed "knebelite. This may be only an intermediate member of the isomorphous series, or it may be a double salt; for the present the name has not been used on account of this uncertainty. The whole olivine group requires a more detailed examination before the true nature of the intermediate mixtures can be ascertained.

These olivines are distinguished by their straight extinction, moderately good cleavage, and symmetrical outlines in thin section. They have a high refractive index, and are generally somewhat brown in the microsection, but are not markedly pleochroic. In slags that have been rapidly cooled the mineral forms very characteristic groups of parallel or radiating crystals.

3. *Silicates of the Rhodonite Group.*—The pure manganese metasilicate (bisilicate), MnO,SiO_2, is one of the end members of a series of mixed crystals which may contain very considerable amounts of the corresponding iron and calcium silicates. The latter must be supposed to be present as the isomorphous compounds, though these have not so far been obtained in the pure state by direct crystallisation from fusion.

The analysis of the rhodonite from slag 6 is given in Table I, 6a. In the present investigation it was found that the limit beyond which the slags yielded fayalite instead of rhodonite was reached when the slag contained a ration FeO : MnO = 73 : 27 (page 856). The rhodonite richest in iron is, therefore, to be expected from a slag approaching this composition; analysis 7a (Table I) shows the iron and manganese oxides in the rhodonite from slag No. 7, which contained approximately above ratio, and it will be seen that the ratio of iron oxide to manganese oxide in the mineral has reached the value 71 : 29.

The amounts of lime, manganese, and iron in these minerals are remarkably close to those in the fluid slags from which they separate. How far the amount of calcium silicate in the mineral can increase is not at present known, but it seems likely that the limit is fairly low, for slag 9, which contained 7·8 per cent. of lime, yielded another silicate which will be described below.

The rhodonites are easily recognised by their very well-marked cleavage in three directions, of which two are parallel with the elongation of the crystals and one is inclined obliquely; by their high extinction angle, and by the oblique termination of the crystals. The cleavage causes the rhodonite slags to be rather friable. The refractive index is high and the mineral is usually somewhat brown in thin section, but not markedly pleochroic. Typical rhodonite crystals are seen in Nos. 3 and 24.

4. *Anorthic Metasilicate of Iron, Calcium, Manganese, and Magnesium.*—Slags that are fairly rich in lime yield a mineral which possesses two cleavages parallel with the elongation, but has little or no cross cleavage; when crushed the mineral forms hard needle-like flakes that readily penetrate the skin. The extinction is nearly, but not quite, straight, and the birefringence of the flakes is noticeably low, an optic axis emerging in a direction nearly normal to each of the cleavages. In thin section the mineral is identified by the absence of cross cleavage, by the oblique terminations, and by the low birefringence and low extinction-angle of the longer sections.

The analysis of crystals separated from slag No. 8 (see No. 23, page 856), is given in Table I, 8a. The mineral evidently contains lime as an essential constituent; it is a metasilicate, but its properties do not seem to agree with those of any of the known minerals of similar composition.*

Fig. 1. THE TERNARY SYSTEM FeO-MnO-SiO₂

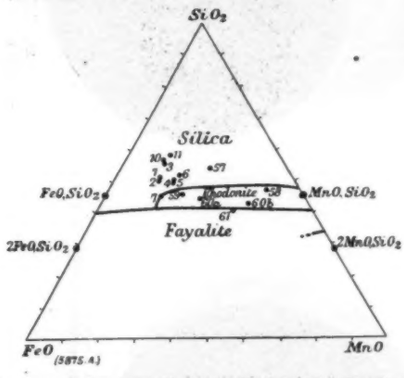


Fig. 2. APPROXIMATE DIAGRAM OF BINARY SYSTEM FeO·SiO₂

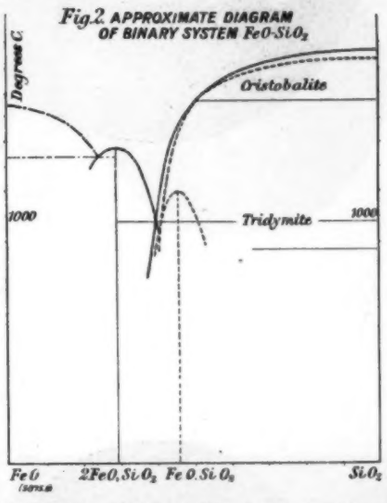
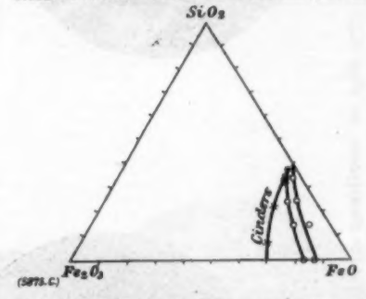


Fig. 3. COMPOSITION OF MELTS CONTAINING SiO₂, FeO, AND Fe₂O₃ IN CONTACT WITH FURNACE GASES UNDER VARYING CONDITIONS (THREE SERIES).



DESCRIPTION OF THE MICROSTRUCTURE OF THE SLAGS IN TABLE I.

The reference numbers are those of the analyses in Table I, and the sections described are, unless otherwise indicated, from the pieces analysed.* It is of some interest to compare the appearance of the transparent section with that of the polished slag under vertical illumination, and a few typical examples have been treated by both methods.

No. 1 (No. 1, page 854.)—The free silica is mainly present as tridymite, in plates which have a lath-shaped section. Among these are a few rounded crystals of cristobalite. The ground-mass is fayalite, which has idiomorphic outlines against small patches of residual brown gas. The silica of the eutectic residue (fayalite-silica) has largely been precipitated on the numerous flakes of tridymite already present; in one portion of the slide, however, the section passed through a crack in the slag into which this residue had drained, and here the silica had crystallised in a second (eutectic) generation, apparently a little later than the accompanying fayalite which forms about four-fifths of the eutectic (No. 5) [E 11,890].

No. 1. *Polished Section* (No. 2, page 854).—The tridymite is dark, while the glass is lighter in tone and somewhat mottled, owing to the presence of crystallites. The light constituent is the fayalite, its outlines against the glass often exhibit the symmetry of the olivine group. The glass contains a few small bright crystals of magnetite.

No. 2.—This analysis is very nearly the same as No. 1, but the structure suggests more rapid cooling. Cristobalite is the first mineral to freeze, in extensive dendritic growths which are imbedded in a fine-grained ground-mass of fayalite with a little brown glass [E 11898].

No. 3 (No. 14, page 855).—Sample taken from the centre of a slag-ball. The free silica is present as large dendrites of cristobalite imbedded in a ground-mass of fayalite and glass. In the larger patches of ground-mass the second (eutectic) generation of silica has crystallised in small grains between the fayalite crystals [E 11901].

No. 4 (No. 3, page 854).—Cristobalite (with some tridymite), in scattered plates that show the typical ladder-like section, has been followed by rhodonite in obliquely terminated anorthic crystals that are imbedded in a considerable amount of brown glass [E 11892].

No. 4 *Polished Section* (No. 4, page 854).—Tridymite, dark; the glass, which is intermediate in tone, contains skeletal octahedra of magnetite; half-tone, rhodonite.

A section taken from the quickly cooled layer, about 3 in. from the outside of the slag-ball, shows that the silica has there been precipitated in numerous small rosettes which occur imbedded in the other constituents (No. 15, page 855), [E 11891].

Nos. 5 and 6.—The structure in these sections is very similar to that of No. 4.

No. 7 (No. 24, page 856).—This slag is of unusually low acidity and contains no free silica; the large crystals of rhodonite which form the bulk of the slag are separated by a brown glass in which can be seen narrow elongated crystals of fayalite. The structure is very similar to that of one of the slags figured by Vogt (No. 60a), which differs chiefly in containing a lower ratio of iron to manganese [E 11897].

No. 7. *Polished Section* (No. 12, page 856).—The edges of large rhodonite crystals are partly seen at each side of the photograph. In the centre is an area of glass containing small rhodonite crystals. Two crystals of fayalite of a paler tint than the rhodonite, are imbedded in the glass; one has symmetrical outlines, the other is partially included in one of the large rhodonite crystals.

No. 8 (No. 23, page 856).—This slag is of rather low acidity and contains no free silica. The anorthic metasilicate described above is the principal mineral and occurs in flat elongated crystals, which sometimes attain a length of several inches and are often hollow, the interior being filled with glass. The interstitial glass contains many small curved crystals of the same mineral. The analysis of the separated silicate is given in Table I, 8a [E 11896].

No. 9 (No. 7, page 855).—Plates of cristobalite with the usual ladder-like section have been partially enveloped by elongated crystals of the anorthic metasilicate; the interstices are filled with a brown glass in which are narrow lines of fayalite. The structure of the glass

* A summary of some recent papers on silica has been given in ENGINEERING, December 6, 1918.

† Journal of the Iron and Steel Institute, 1918, No. II, p. 104.

‡ American Journal of Science, 4th series, 1913, vol. xxxvi, p. 331.

§ Bulletin de la Société de Mineralogie, vol. xl, p. 44.

* A description of this substance has been communicated to the Mineralogical Society, at the meeting on March 18, 1919.

* Duplicates of many of these slags have been presented to H.M. Geological Survey; the numbers preceded by the letter E refer to registered sections in the Survey collection. The authors desire to express their thanks to the Director for permission to figure slide E 11897 (No. 24). The other photographs are from sections prepared by Mr. J. Lomax.

THE ACID HEARTH AND SLAG.

(*For Description, see Page* 852.)

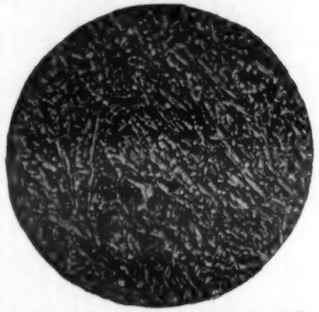
No. 1. × 35. Acid slag; tridymite in groundmass of fayalite, &c.

No. 2. × 425. The same, polished section.

No. 3. × 35. Acid slag; cristobalite in groundmass of rhodonite, &c.

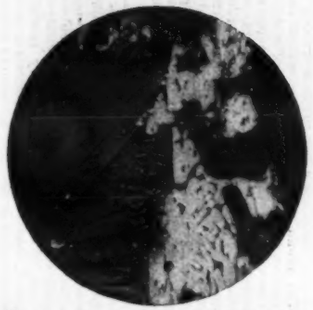
No. 4. × 425. The same, polished section.

No. 5. × 90. Eutectic of silica and fayalite with brown glass.



No. 6. × 35. Section through a nodule from an acid slag; tridymite, cristobalite and rhodonite.

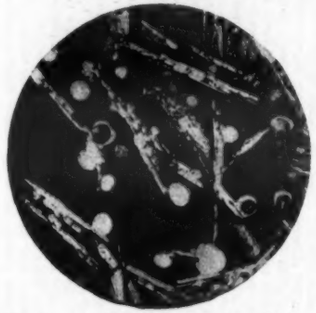
No. 7. × 35. Acid slag; cristobalite in metasilicate and glass.



No. 8. × 425. The same; polished section; cristobalite, metasilicate, fayalite and glass.

No. 9. × 20. Acid slag; spoon-sample. Thin section in oblique illumination.

No. 10. × 35. Acid slag; spoon-sample, reheated at about 1200°C. for 18 hours.

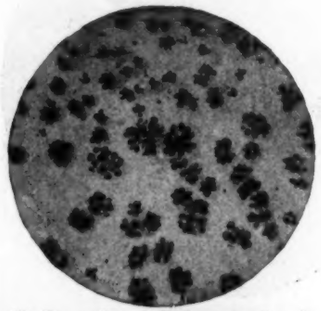


No. 11. × 35. Acid slag; sample 1, reheated at about 1200°C. for 18 hours.

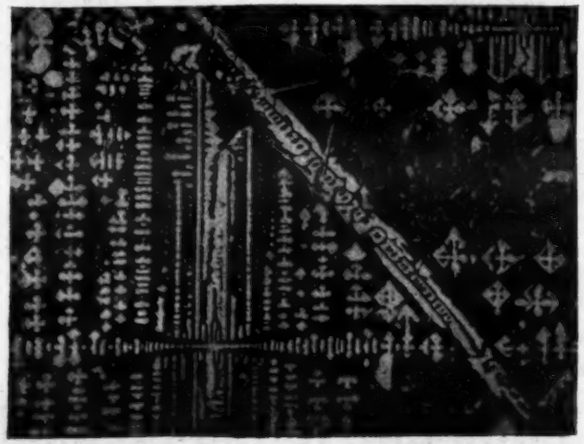
THE ACID HEARTH AND SLAG.

(*For Description, see Page* 852.)

No. 12. × 425. Acid slag, polished section; rhodonite, fayalite and glass.

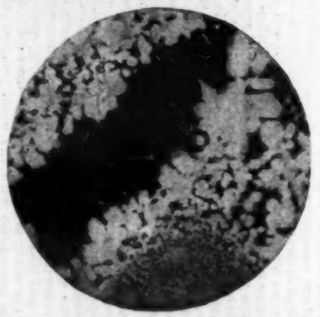


No. 13. × 425. Acid slag, spoon-sample, polished; rosettes of silica in glass.

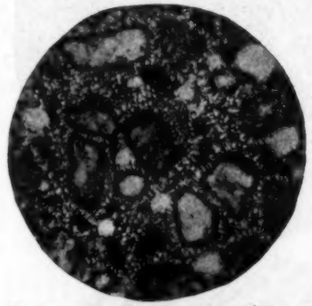


No. 14. × 20. Acid slag; cristobalite in ground mass of fayalite, &c.

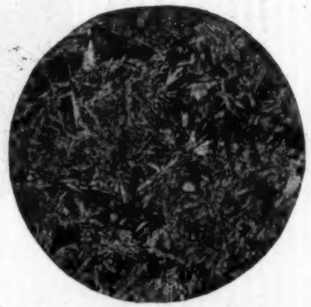
No. 15. × 250. Rosettes of silica in rhodonite and glass.



No. 16. × 35. "Bank" of acid furnace; cristobalite with magnetite, &c.

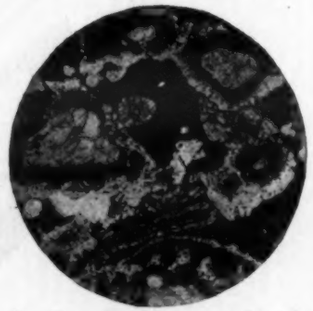


No. 17. × 35. Freshly-made patch in an acid hearth; sand-grains partially altered to tridymite.



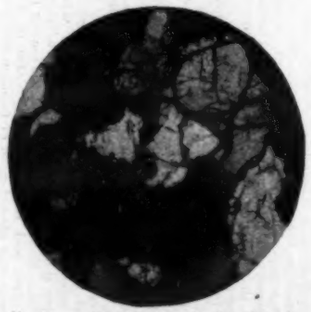
No. 18. × 35. Older portion of an acid hearth; alteration to tridymite completed.

No. 19. × 35. Surface of acid hearth; tridymite passing into cristobalite, with fayalite.



No. 20. × 35. Lower part of hearth next brickwork; gannister and sand in slag with fayalite.

No. 21. × 18 Dendritic cristobalite with interstitial slag, from the centre of a slag-ball.



No. 22. × 80. Sand-grains from hearth with further growth of quartz in optical continuity. × d nicols.

is really complex, as will be seen in No. 8, page 854, which shows a polished section of the same slag. The dark irregular grains are part of one of the large plates of dendritic cristobalite, while the metasilicate is seen on the opposite side as a sharply angular crystal, and the intervening space represents one of the dark areas in the transparent section. This last portion is composed almost entirely of small crystals; one of the bands of fayalite is visible as a series of crystals, in parallel orientation, which appear much brighter than the metasilicate; the remaining space is occupied by a dark constituent, which may still be glassy and which contains thin curved metasilicate crystals that are in places evidently continuous with the larger crystal of the same mineral.

Nos. 10 and 11.—The specimens and microsections used for the following description were kindly transmitted by Mr. Allan B. Dick, to whom the authors desire to express their thanks.

The slag was made many years ago in a Siemens furnace in Scotland; it was collected and preserved on account of the presence in it of remarkable spherical nodules, which measured from ¼ in. to 2 in. in diameter. When the slag was broken the nodules readily became detached from the matrix through the presence of a porous layer at the surface of the spheres; when split open they showed a crystalline fracture radiating from the centre. Microsections show that the matrix (No. 25) is a typical acid slag containing plates of dendritic cristobalite in a ground-mass of fayalite and glass; the nodules (No. 6, page 854) contain scattered flakes of tridymite, together with a certain amount of cristobalite, in small rounded grains, but the ground-mass is rhodonite, which has a radiated structure; this, too, is the normal structure of a certain class of acid slags and resembles Nos. 4, 5 and 6. As will be shown later, the acid slags may be grouped according to the silicate present, the formation of fayalite or rhodonite being conditioned by the ratio of iron to manganese in the liquid slag. The analyses of the slag matrix (No. 10) and of one of the nodules (No. 11) are given in Table I; these analyses lie very close to the critical analysis separating the two classes (*cf.* Fig. 1). When a slag of this composition has become super-cooled both structures are possible, and the nature of the silicate which crystallises may be determined by accidental causes, such as the introduction of suitable nuclei. In the present instance it would appear that, when the mass was super-cooled with respect to silica and rhodonite, crystallisation of rhodonite was initiated at a few centres, from which grew spheres of rhodonite slag in which the free silica was deposited as small grains that are often enclosed within the rhodonite crystals. The acid slags contain a certain amount of gas, and the liberation of this from the slag as it crystallised will no doubt account for the porosity at the surface of the nodules. When the spheres had grown to a certain size, the surrounding liquid, which had meanwhile deposited large dendritic plates of cristobalite, solidified with the formation of fayalite, so that the nodules of rhodonite slag were enclosed in a normal fayalite slag.

The Ternary Diagram, FeO–MnO–SiO_2.

The triangular diagram represented in Fig. 1, page 853, has been constructed from the analyses of the slags described in the preceding section. The points shown represent the composition of the slags as given in Table I, the number placed near each point being that of the sample in the table. Owing to the presence of small amounts of other substances, the total percentage of the three oxides is always somewhat below 100, and it was, therefore, necessary to adopt a fixed order in plotting the values; the method used was to divide the base of the triangle in the ratio of the iron and manganese oxides present and to mark off the representative point upon the line joining the apex to this division of the base, at a value corresponding with the percentage of silica present. The diagram thus obtained can be regarded as approximately that of the ternary system, but it must necessarily remain incomplete until a full determination of the system has been made by the experimental preparation of those melts which are not encountered among the acid slags; for the present it may serve as a guide for the study of the materials of the acid process.

In accordance with the usual practice, the diagram has been divided into areas; each area includes the compositions of those melts from which one of the minerals concerned is the first to separate on cooling. In most of the slags analysed silica was the first mineral to freeze, the slags being generally more acid than those described by Vogt. The silica was followed by a silicate, and it was soon observed that the slags could be divided into two groups, in one of which the silica was followed by rhodonite, in the other, by fayalite. The factor determining which silicate shall form is the ratio between the FeO and MnO in the slag, the two classes being separated by the critical ratio FeO : MnO = 73 : 27; with more manganese, rhodonite is obtained; with more iron, fayalite. When the slag deposits free silica its composition changes during the separation of the silica along a line which is the continuation of that joining the apex SiO_2 with the representative point of the slag; when the liquid has attained the composition of the eutectic, in the absence of super-cooling, the silicate and silica separate together in the eutectic proportion.

The binary system, SiO_2–MnO, has been described by Doerinckel, whose diagram has recently been reproduced by McCance.* The points in Fig. 1, on the line SiO_2–MnO, have been taken from these data. In the binary diagram the silica-line meets the rhodonite-line practically at the melting point of rhodonite. There is thus no eutectic between the two compounds, the separation of silica being followed by that of the rhodonite. From the structures previously described it is clear that, in the ternary diagram of Fig. 1, the boundary between the silica and rhodonite areas must pass between slags 4 and 5, and slags 7 and 59. The proportion of free silica in the fayalite slags is greater than that in those yielding rhodonite, and the boundary must therefore turn sharply downwards as it approaches the ratio FeO : MnO = 73 : 27. Beyond this ratio fayalite separates, and at this point, therefore, the three boundaries between fayalite, silica, and rhodonite must meet.

The boundary fayalite-silica represents a well-defined eutectic. A true eutectic structure is sometimes to be observed in the mill cinders (soaking-pit cinders), where, as far as can be judged from microsections, the eutectic contains about 40 per cent. total silica and 60 per cent. FeO. The boundary is probably fairly horizontal between this and the ternary eutectic point. The eutectic structure is not well seen in the slowly cooled slags, but in slag No. 3 (No. 14, page 855) the ground-mass consists of an aggregate of silica and fayalite in about the eutectic proportion. In slag No. 1 the section had passed through a vein of similar eutectic material that had flowed into a crack during the solidification; this is seen in No. 5, page 854.

Like the preceding boundary, that between rhodonite and fayalite appears to be nearly horizontal; it passes between Vogt's slags 60b and 61, and meets the side of the diagram at MnO = 60 per cent.

Tephroite is stated to be unstable at its melting point, and the boundary between tephroite and MnO starts from SiO_2 = 32 per cent. Concerning the further course of this boundary and the behaviour of the less siliceous melts no information is obtainable from the slags here under discussion.

In concluding this account of the ternary diagram, it may perhaps be remarked that the similarity between the systems FeO–SiO_2 and MnO–SiO_2 is very strongly marked. It is true that the metasilicate of iron does not appear, but this does not imply any great difference in stability between the two metasilicates; the rhodonite surface evidently passes beneath that of silica by a gentle inclination, which suggests that the stability line or melting-point curve of the iron member of the rhodonite group is only slightly below that of silica. This may be represented in the manner shown in Fig. 2, page 853.

Slags containing Lime.

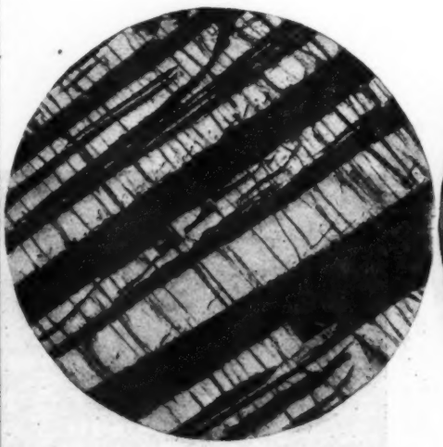
Small amounts of lime are present in many of the analyses already discussed. The corresponding silicates of lime are soluble isomorphously in both rhodomite and fayalite, and their presence does not at first greatly disturb the equilibrium relations. With large amounts of lime (over 8 per cent.) another mineral is formed which, like rhodonite, is a metasilicate containing manganese, calcium, and iron (page 853). The long crystals have a brilliant cleavage, and in slags of which the composition approaches that of the pure silicate the mineral is the cause of great inconvenience when the slag is crushed for road-metal. Vogt examined many lime slags, but these were in general richer in alumina or magnesia; the minerals observed include augite and olivine, but the present silicate does not seem to have been encountered.

For those slags which yield free silica, the nature of the silicate will be determined by the ratio of the three bases FeO, MnO, CaO; these could conveniently be represented in a triangular diagram, but many more analyses will be required before even this section of the quaternary system can be described with sufficient accuracy.

In order to examine the growth of tridymite at temperatures somewhat above the eutectic point, but below that at which the inversion to cristobalite occurs, two specimens of slag of similar composition, in the glassy and crystalline states respectively, were enclosed in a steel cylinder and heated for eighteen hours at a temperature of approximately 1300 deg. C. The case was withdrawn from the furnace and cooled in air; when the pieces were removed it was found that they had retained their shape, but had become welded together. The structure of the reheated glassy slag (part of a spoon sample) is shown in Fig. 10 (page 854); it consists of plates of tridymite in a glass that is stained by a slight oxidation. The crystalline sample slag No. 1 (No. 1, page 854) is shown in No. 11, page 854; the plates of tridymite originally present have been partially redissolved by the melted fayalite, and remain imbedded in a brown glass. It is clear from this experiment that tridymite is really stable in contact with the melt at 1300 deg. C. The structures obtained resemble those found in the acid hearth.

No. 23. × 20. Acid slag; anorthic metasilicate with brown glass.

No. 25. × 20. Acid slag; cristobalite in a ground mass of fayalite and glass.



No. 24. × 20. Acid slag; rhodonite with brown glass containing narrow crystals of fayalite.

No. 26. × 15. Skeletal octahedra of cristobalite in parallel growth on a plate of the same mineral.

The Structure of Reheated Acid Slags.

The Structure of quickly cooled Slag Samples.

In the small "spoon samples" (2 in. to 3 in. in diameter) which are withdrawn from the slag during the process, a very interesting structure is to be observed;

* Journal of the Iron and Steel Institute, 1918, No. I, p. 246.

it is probably the same as that referred to by McCance,* and consists of very minute crystals or crystalline rosettes imbedded in a glassy matrix. Under vertical illumination the crystals appear dark grey in contrast with the lighter background (No. 13, page 855), this tint is similar to that always given by the crystalline forms of silica. In transmitted light the particles in thin sections are seen to be transparent and colourless; their refractive index is much lower than that of the glass in which they occur, and also in crushed material was found to be lower than 1·55. It is thus fairly certain that they are a form of silica; this was confirmed by digesting the slag in dilute hydrochloric acid, when the particles were left as a fine white powder which volatilised with hydrofluoric acid. The mineral has been mentioned by Vogt, who observed it in very acid slags, and surmised that, if a silicate, it contained a very high percentage of silica; he termed it the "enamel-mineral," on account of the dull lustre which it imparts to the slag.

The particles are common in acid spoon samples, and can appear even in quickly cooled melts which would normally yield fayalite. They are sometimes to be observed in the crystalline slags where super-cooling has occurred; thus the exterior of the slag-ball which yielded analysis No. 4, at a distance of 3 in. from the surface, contained rather large rosettes imbedded in the other constituents (No. 15). As Le Chatelier has remarked, glasses generally devitrify with the formation of cristobalite, so that it is most probable that the particles are this mineral and not tridymite.

As soon as a spoonful of slag is withdrawn from the bath, the furnace gases, and, later, the air, begin to oxidise the upper layer. When the cold sample is fractured, the surface is seen to be tinted a deep brown or black to a depth which varies with the character of the slag, and may extend to a distance of $\frac{1}{8}$ in.; this action takes place chiefly before the slag is set, for samples which have been covered with carbon immediately on withdrawal from the furnace still show an oxidised layer. A section through a typical spoon sample of a slag comparatively free from lime is shown in No. 9. Even in the thin section (about $\frac{1}{1000}$ in.) the slag is rather opaque, and the structure is best revealed by oblique illumination, which was used in taking the photograph. The pale glassy centre of the sample is seen in the lower part, and above it the dark oxidised layer in which are several gas bubbles. It is a curious fact that the limit of the crystallisation which extends from the surface downwards is marked by the lower dark boundary; in other cases the deep-brown colour extended beyond the crystallisation.

Some idea of the extent of the oxidisation may be obtained from the following analyses of the various layers in one of these spoon samples:

	FeO. Per Cent.	Fe_2O_3. Per Cent.
Top layer	28·9	2·71
Middle layer	30·2	1·3
Bottom layer	30·1	1·42

It will be understood that in testing spoon samples for Fe_2O_3 the top layer must always be rejected.

In Part III of this paper the view will be advanced that gas oxidation takes place partly through the absorption of oxygen by the upper layers of the slag. The depth of the oxidised skin in the spoon sample affords a useful indication of the power of the slag to absorb oxygen. Thick slags invariably show less penetration than thin slags, as is well seen in samples taken before and after an ore addition. Again, limey slags generally have a thin oxidised layer, and it will be shown later that such slags retard the gas-oxidation of the charge.

PART II.

The Acid Hearth.

Although the acid hearths which have been examined during the course of the present investigation were originally made of silica stone and sands containing over 96 per cent. of silica, yet the analyses of these hearths, taken after they had been in use for considerable periods, invariably showed a much lower silica content, and micro-sections through different parts revealed the presence of large quantities of slag. The analyses of pieces from various positions in three old hearths are given below:—

Table II.

	1.	2.	3.
	Per Cent.	Per Cent.	Per Cent.
SiO_2	67·00	67·20	68·10
Fe_2O_3	7·70	0·30	0·90
FeO	22·90	19·80	23·10
MnO	1·10	6·60	3·90
Al_2O_3	0·28	2·80	2·10
CaO	0·50	2·20	1·10
MgO	0·05	0·04	0·15
TiO_2	0·03	1·20	..
	99·56	100·14	99·35

1, taken a few inches beneath the surface at a point about 2 ft. below the wash (Nos. 18 and 19, page 855). 2, taken near the limit of penetration of slag in the bricks beneath the crushed ganister used in making the lower part of the hearth. 3, taken just above the top layer of bricks (No. 20).

The above analyses may be regarded as representative of the composition of acid hearths which have been in use for some weeks and where lime has not been added in any great quantity to the slags.

* *Loc. cit.*, p. 266.

Microstructure.—Nos. 16, 18, 19 and 20 illustrate the microstructure of various parts of the acid hearth.

No. 16.—Bank, near surface exposed to the gas, showing a patch of slag rich in dendritic crystals of magnetite, between which are lighter areas of fayalite and a few plates of tridymite. The white ground-mass is entirely cristobalite and contains smaller slag inclusions. Very little trace of the structure of the original sand grains is to be seen. The presence of the magnetite is no doubt due to the oxidation of the surface layers during the cooling of the furnace [E 11708].

No. 18.—Old bottom (analysis No. 1). Interlacing needles of tridymite in fayalite with areas of brown glass. The position of the original sand grains can still be seen [E 11537].

No. 19.—Another part of the same section; cristobalite and tridymite areas in juxtaposition.

No. 20.—Lower part of the hearth near the brick-work (analysis No. 3). Grains of quartz, sand and ganister, superficially converted to tridymite, in brown glass containing fayalite crystals.

These and similar sections show that the hearth in use consists of a mass of interlacing crystals of tridymite, the interstices of which are filled with slag. For a small distance below the surface the temperature is sufficiently high to cause the formation of cristobalite in place of tridymite. Numerous analyses showed that the proportion of slag is remarkably constant throughout the whole mass down to the limit of penetration, which usually lies in the upper courses of the brickwork. The silica content throughout is generally from 67 per cent. to 70 per cent. During the working of a charge, the average temperature of the hearth will be above that of the melting point of the interstitial slag; this will, therefore, be fluid and in equilibrium with the excess silica. The amount of undissolved silica at any point will depend upon the temperature and the quantity of slag present. The upper surface of the hearth will be at the temperature of the molten metal while, at the limit of slag penetration, the temperature will scarcely exceed 1000 deg. C.; there is thus a wide temperature variation through the hearth, and the proportion of undissolved silica will consequently decrease towards the upper surface.

Complete fluxing of the hearth in contact with the molten metal is prevented by the additions of quartz sand made in "fettling" the bottom after the charge has been tapped. Towards the end of the process the temperature of the upper layer is not far removed from the melting point of pure silica, and it might be expected that the large amount of impurities present in the hearth (about 30 per cent.) would lower the melting point to such a degree as would bring about complete fusion. The depression of the freezing point of silica by impurities seems, however, to be exceptionally small, the point of complete fusion of a mixture containing as much as 50 per cent. of ferrous oxide was found to lie at about 1500 deg. C., and the freezing point curve must have such a form as that shown in Fig. 2. A similar behaviour of silica has been recorded for other systems.* There can be no doubt that this property of silica plays a most important part in maintaining the stability of the acid hearth.

It will be seen from the analyses (Table II) that the slag present in the hearth resembles generally the ordinary acid slag, such as No. 1, Table I. The ratio of iron to manganese in the hearth is, however, distinctly higher than that in the slag; in accordance with this ratio, the silicate found in the sections is invariably fayalite (*cf.* Fig. 1). A certain amount of metal as well as slag is always left on the bottom after tapping; during the subsequent "fettling" of the hearth this metal will be rapidly oxidised by the flame, and the iron content of the slag will be thereby increased. In order to verify this conclusion, some slag was removed from the hearth just before the sand additions were made and after the banks had been repaired. The iron and manganese contents of this sample and of the finishing slag were then ascertained, the quantities found being as follows:

	FeO. Per Cent.	MnO. Per Cent.
Finishing slag	27·1	13·2
Hearth slag	36·2	4·5

The hearth slag has clearly been enriched with iron oxide, and the ratio of iron oxide to manganese oxide in this residual slag is very similar to that found in the hearth itself.

Changes occurring on "Making" and "Fettling" the Hearth.—In view of the comparatively low silica content of the hearth in actual service, it is somewhat surprising that the smelter almost invariably requires a very high degree of purity in the sand used. Even in the case of a sand which would be rejected, owing to a low silica content, the quantity of impurity present may still be quite negligible in comparison with the large amount of slag subsequently taken up. Evidently, in requiring a pure sand, the smelter cannot aim simply at the production of a highly refractory hearth, and the degree of purity necessary in the sand employed must therefore be determined by other factors.

There can be no doubt that a combination of properties is essential in a silica sand which is to be used for making and "fettling" the acid hearth. Among the physical properties the grain size, grading, angularity, and angle of rest must all be considered, and these alone form a combination which it would be almost impossible to define within the limits of any practical specification.† Even if a sand is satisfactory in these respects it may still be rendered unsuitable by its chemical composition. In this connection, three indirect ways in which small amounts of impurity will affect the quality of a sand may here be mentioned.

1. The smelter attaches great importance to the ease with which a sand can be made to lie at a steep angle on the banks.* This is, of course, largely a physical property, but the presence of small amounts of impurity on the surface of the grains will cause fritting and so assist in the production of a "hard" steep bank, while a greater proportion of impurity, especially in the case of certain fluxes, such as the alkalies, will rather tend to prevent the cohesion of the grains to form a rigid mass and so cause the sand to be "soft." In this respect alumina does not seem to be as harmful as other common impurities.

2. The rate of inversion of quartz to tridymite is greatly influenced by the presence of impurities; the change causes the grains to break up through flawing and crystal growth, with the consequent admission of slag and softening of the mass. Thus it may be said that in general the slower the inversion the better will be the refractory properties of the sand (for temperatures below the melting point of quartz) during the early part of the heat. Since the presence of small amounts of impurity in the mass of the grain has a considerable accelerating action on the change, it is clear that on this account, whatever the composition of the external layer, the interior of the grain, at any rate, should have a very high degree of purity.

3. It would naturally be supposed that the higher the silica content of the hearth the more satisfactory would be its service. Experience, however, indicates that it would be impossible to carry out the process continuously upon a pure silica hearth. The softening action of the fluid slag content is of the greatest value in counteracting the tendency of the hearth to crack while cooling between successive heats. Such cracks when formed are quickly filled with molten slag, or even with metal from the bath, and during the "boil," as the temperature of the hearth increases, the fluid area extends, and may either penetrate the bottom or cause a portion to be detached and so give rise to a "hole."

After the furnace has been tapped a certain quantity of slag and metal is always left on the bottom. As far as possible this is removed by the smelter, but some inevitably remains, especially in the grooves and holes present. An important function of the sand which is added in "fettling" is to absorb this residual slag, so as to produce a uniform layer which replaces the material removed from the hearth during the previous heat. If the sand employed contains any considerable amount of impurity, the insterstices of the new layer will become filled with fused material, which will render the whole mass non-porous before the underlying viscous slag has time to penetrate. The slag thus confined beneath the new sand becomes a source of weakness when the temperature of the furnace is again raised, and the whole mass of sand may separate from the hearth and float up to the surface of the bath.

Where a hole in the bottom has been repaired with suitable sand, the silica content of the new part will eventually approximate to that of the hearth in general, owing to the absorption of slag. During the subsequent heat the quartz of the sand undergoes a gradual transformation to tridymite (this was complete in a piece which came up two hours after the boil), but the shape of the sand grains is only slowly obliterated. Each grain becomes surrounded by a fringe of tridymite (No. 17), and these fringes grow until the structure has changed to a loosely felted mass of tridymite crystals (No. 18), the spaces between which are filled with flud, slag.† The stability of the hearth will thus depend on the viscosity of the interstitial slag and on the rigidity of the tridymite network. This structure may be compared with that of plaster of Paris saturated with a liquid which fills the pores between the needles of hydrated calcium sulphate; in such a structure a relatively small proportion of solid matter will suffice for the production of a rigid mass.‡

A striking instance of the failure of an impure sand that was used for repairing a hole in the hearth may here be mentioned. The sand contained about 5 per cent. of alumina as kaolin, and traces only of other impurities. The whole patch floated up during the "boil," and was found to be pure white in fracture and completely free from included slag. Most of the silica had been transformed to cristobalite, but in places the material was much denser, resembling porcelain, and on sectioning was seen to consist of very closely packed quartz grains surrounded with glass containing sillimanite (Al_2SiO_5) needles. The quartz grains were, in many places, regrown, as shown in No. 22, where the outlines of the original sand grains can clearly be seen within the larger crystals that have grown in continuity with them. The deposition of quartz in this way is remarkable; it is probably due to the retention of water from the kaolin,

*American Journal of Science, 4th Series, vol. xxxvii, p. 487.

† See P. H. G. Boswell, "Refractory Sands," 1918, p. 58.

* It is important to observe that the temperature of the sand after being placed upon the banks during fettling may be considerably lower than has sometimes been assumed; the gas is sometimes off for several minutes before fettling is completed, and the cold sand probably does not reach a temperature exceeding 1000 deg. C. before all movement has ceased.

† There can be little doubt that the presence of the absorbed slag in the new sand greatly facilitates the formation of the tridymite crystals.

‡ At the upper surface of the hearth, where cristobalite is present instead of tridymite (Fig. 19), the structure is probably virtually fluid, but this thin layer is doubtless retained in position by its viscosity. In this connection, it is interesting to note that the silicon content of the roof-drip was found to be very little lower than that of the hearth.

owing to the pressure of a heavy piece of metal resting upon the patch.

The foregoing considerations make it clear that the purity of the sand used for the acid hearth is of great importance. The need for a sand which will not fuse to a solid mass, but will retain its porosity at the temperature of the furnace, demands material of higher purity than would be required if it were merely necessary to provide a refractory lining, and for these reasons alone the silica content must be considerably higher even than that required in a silica brick directly exposed to the flame in the walls or roof of the furnace.

Presence of Ferric Oxide in the Hearth.—The proportion of ferric oxide in the hearth analyses is lower than the average amount present in the finishing slags. This is the case in spite of the fact that air and gas play upon the hearth after tapping and cause the formation of much ferric oxide at the surface, as shown by analysis No. 1 in Table II. It is clear, therefore, that a reduction of ferric oxide must occur during the subsequent heat, otherwise the percentage in the lower part of the hearth should be much greater. Among the causes contributing to this reduction may be mentioned—(1) The penetration of carbon monoxide, which probably diffuses fairly readily in the silicates at the hearth temperatures. (2) The penetration of metal into the hearth. (3) The decomposition of ferric oxide by silica at high temperatures; this will be further discussed in Part III.

The presence of ferric oxide in the hearth has a certain practical interest, for it is commonly remarked by the smelter that the bottom "works" the metal; this effect is very probably due to the ferric oxide formed in the surface layer after tapping.

The study of the acid hearth raises many questions to which no definite answers can yet be given. The actions of chromium and manganese slags, for example, require examination, for while the former tend to preserve the hearth the latter often cause a rapid corrosion of the surface.* Manganiferous metal has at times a similar effect to that of the slag, but here it is necessary to take into account the reducing action of manganese on silica; † the replacement of silica by manganese oxide has a double effect in diminishing the acidity of the surface layer of the hearth; and a small loss of silica in this layer will suffice to render it dangerously fluid.

PART III.

The Molten Slag.

The durability of the acid hearth is partly dependent on the composition of the molten slag with which the banks are in contact during the process. In the course of work on this subject numerous analyses of the slag at various stages were obtained, and the following pages contain a discussion, based on these experiments, of some of the reactions occurring in the liquid slag. The manner in which the composition of the slag is regulated by the furnaceman is first indicated, and an account is then given of observations on the part played by the slag in the oxidation of the metalloids. Gas-oxidation is an important feature in the process, and was found to be closely connected with the action of ferric oxide as a carrier of oxygen from the gas to the metal.

1. *Regulation of the Acidity of the Slag.*—In judging the condition of the slag in the acid process the smelter is chiefly guided by its viscosity and activity. A slag high in silica will be thick and inactive, while a slag which is too basic will be thin and dangerous to the banks, owing to the readiness with which it will dissolve silica. Up to and during the "boil" the elimination of the metalloids is accompanied by the removal of iron oxide from the slag, so that if the reaction is allowed to proceed for a time without further ore additions the slag gradually thickens, owing to its increasing silica content. The correct viscosity has, therefore, to be maintained by frequent additions of iron oxide. At first, on account of the rapid thickening action the metal, large additions may safely be made without damage to the banks, but as the metal begins to drop off the "boil" this thickening action becomes slower, and the furnace must then be fed with smaller or less frequent additions of ore. An excess of iron oxide in the slag at this stage is not rapidly removed, and if too thin a slag is obtained after the metal has dropped off the "boil" serious damage to the banks may result, especially if the temperature is high.

2. *The Use of Lime.*—Like iron oxide, lime thins the slag, its effect being about equal to that of an equivalent weight of ferrous oxide. If a limey finishing slag is too thin it will attack the banks much as does an iron slag of similar viscosity. When using lime, therefore, the smelter must still be guided by the viscosity of the slag, although perhaps somewhat more latitude in this respect is allowable. In general, it seems to be the practice to work to approximately the same degree of viscosity whether lime is present or not; and since, at a given temperature, the viscosity is determined chiefly by the silica content, it follows that the sum of the basic oxides present in similar slags of varying composition must be about constant. Seeing that lime is not removed from the slag during the process, as is the case with iron oxide, its use must be accompanied by a lowering of the iron content; the quantity of lime present in the finishing slag will be the sum of the amounts added, and, as the total bases remain the same, the quantity of iron oxide present will be correspondingly decreased, provided, of course, that sufficient carbon is present to remove it. Lime additions may thus be said to lower "automatically" the iron content of a slag by a process which is quite unconnected with any chemical equilibrium between these bases and silica.

3. *The Removal of Carbon by Gas-Oxidation.*—As is well known, the three principal elements to be removed from the charge by oxidation in the acid process are silicon manganese, and carbon. Two sources alone are available from which the necessary oxygen can be obtained; they are first, the ores added in "working" the charge, and second, the oxygen content of the gas which plays continually upon the surface of the bath, for it has already been shown that the hearth itself contains very little available oxygen. By oxidation with ore the yield is increased; with gas-oxidation it is diminished.

The amount of oxygen obtained from the two sources, either throughout or during any period of the process, can be ascertained with a fair degree of accuracy from the analysis of slag and metal samples taken before and after the addition of a measured amount of ore. From such data it is easy to calculate the weight of the metalloids removed and to compare the amount of ore used with that theoretically required in the absence of gas-oxidation. A table of the "percentage of gas-oxidation" with different charges has been given by Matthewman and Campion,* but without the data on which it is based. The following examples will serve to indicate the extent to which gas-oxidation has occurred in two charges—(*a*) Worked in the usual way without any lime additions; (*b*) with lime additions.

(*a*) The charge (100 tons) contained, when melted and just before the first feed of ore was given :—

	Per Cent.
Silicon	1·10
Manganese	0·50
Combined carbon	2·20

On tapping, the carbon in the bath had been reduced to 0·10 per cent. This charge was worked with an ore consisting of nearly pure ferric oxide. The oxidation of the silicon produced 2·35 tons of silica, and since the average analysis of the slag throughout the process showed silica 50 per cent. and iron 25 per cent., the oxidised silicon would require 1·7 ton of ferric oxide in forming the additional slag; by this reaction 0·17 ton of oxygen was liberated, for practically all the iron of the acid slag is in the form of ferrous oxide.

The total oxygen required for the removal of the metalloids was silicon, 1·25 ton; manganese, 0·14 ton; carbon, 2·80 tons; making a total of 4·19 tons; of this oxygen 0·17 ton was supplied by the ore (1·7 ton) in forming slag, and the residue 4·02 tons, in the absence of gas-oxidation, would have to be supplied by the reduction of 13 tons of ore, so that in all 14·7 tons of ore would have been consumed. The actual quantity of ore used was only 9·0 tons,† and, therefore, the additional oxygen required for the completion of the reactions must have been derived from the gases.

The removal of silicon and manganese took place rapidly as the metal was brought to the "boil," during which time a large part of the ore used was added. The gas-oxidation, which operates throughout the process must thus be chiefly concerned in the much slower removal of the carbon, and it may be said that about 5·7 tons of the ore (the amount required by theory) were used to remove the silicon and manganese, and to make slag and the remaining 3·3 tons to remove the carbon. If the whole of the carbon had been oxidised by means of the ore, 9·3 tons would have been consumed instead of 3·3 tons, and it is clear, therefore, that approximately two-thirds of the carbon was eliminated by gas-oxidation and only one-third by ore additions.

(*b*) Samples of slag and metal were taken from a furnace when the carbon was about 0·80 per cent. The charge was then worked almost entirely with lime (CaO); as the slag thickened after each addition, more lime was added, until the carbon had fallen to 0·12 per cent. Towards the finish the slag became very inactive, and about 2 cwt. of ore were, therefore, used. The analyses of slag and metal samples were as follows :—

	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon in metal ..	0·80	0·50	0·20	0·12
Ferrous oxide in slag ..	35·50	30·0	21·20	21·90
Ferric oxide	0·10	0·10	0·15	0·30
Lime	2·0	—	—	13·8

Weight of charge, 70 tons; slag, 10 tons.

It will be seen that during this period, 0·48 ton of carbon was eliminated; this amount would require at least 0·64 ton of oxygen, of which 0·03 ton was obtained from the ore added, and 0·3 ton from the reduction of the FeO in the slag. The remainder, 0·31 ton, must have been derived from the gases, so that, in this instance, about 50 per cent. of the carbon was removed by gas-oxidation.‡

The amounts of gas-oxidation found in the above examples are similar to those given by Matthewman and Campion. The exact amount occurring in any particular instance will depend, however, upon a number of factors, among which must be included temperature, character of slag, quality of ore used, relative quantities of gas and air employed, and the speed of working.

4. *Physical Conditions which Obtain during the Process.*—Before the chemical reactions involved in gas-oxidation can be considered, it is necessary to examine the physical conditions under which the process is carried out. As soon as the charge is melted, the metal becomes covered with a layer of slag, and from this stage onwards the slag, especially during the boil, is continually traversed by bubbles of CO gas evolved from the metal below. These will saturate the slag with CO, and will effectually prevent the penetration of the furnace gases, which might otherwise reach the lower layers by diffusion or convection and react directly with the metal.

Throughout the process the slag is constantly in contact with both the metal and the gas, and under given conditions its degree of oxidation at any time will depend on the relation between the reducing action of the metal and the oxidising action of the gases.

Beside the slag-metal and slag-gas reactions, there is also that which occurs between the metal and the gas; evidence will be given later showing that a considerable amount of gas-oxidation during the "boil" takes place by direct action of the gases on the numerous globules of metal which are continually being thrown up to the surface of the slag.

5. *Reaction between Metal and Slag.*—The oxidation of the metal by the slag may be regarded as purely a surface reaction, the only exception to be considered being the possibility that FeO passes into the metal from the slag, and is there reduced by the carbon. The reacting surface, and consequently the speed of oxidation, is subject to wide variations at different stages of the process, owing to the suspension of fine globules of metal in the slag through the ebullition of gas from the bath. The percentage of this suspended metal in spoon samples of slag taken at various periods was determined by removing the globules from the crushed sample with a magnet; the following results are representative of several series obtained in this way :—

Period.	Suspended Metal. Per Cent. by Weight.
Melting (very large globules) ...	12·0
Before boil (small pellets)	0·5
Boiling	5·0
Off the boil, c.c. 0·25 per cent. ...	0·1
Tapping, c.c. 0·15 per cent. ...	0·1

These figures show that as soon as the carbon reaction begins the number of metal globules in the slag very greatly increases, and there can be no doubt their presence is due to the agitation caused by the evolution of CO. When it is considered that in, say, a 100-ton charge no less that half a tone of metal is in suspension in the slag during the boil and is constantly being renewed, it is not surprising that the speed of removal of carbon during the boil is considerably greater than that which can be obtained in the finishing stages.

The following analyses of slag globules and metal samples taken simultaneously will suffice to indicate the extent to which the globules lose their carbon content during their short stay in the slag.

Carbon in Metal. Per Cent.	Carbon in Globules. Per Cent.
2·11	1·76
1·99	1·72
1·36	1·26
0·80	0·75
0·56	0·56

6. *Reaction between Slag and Gas.*—Like the preceding, the oxidation of the slag by the gas is a surface reaction, but in this case the action is very probably aided by the physical solubility of the gases in the uppermost layers of slag. The rate of oxidation will depend on the area of the bath, on the temperature, on the composition of the oxidising gases which play upon the slag, on the amount of FeO in the slag, and on the slag viscosity.

It may be remarked here that this last factor in particular affects not only the reaction between the gas and slag, but also that between the slag and metal, and limits the convection currents, which no doubt play a great part in the transference of iron oxide (Fe_2O_3) to the metal. For these reasons the viscosity of the slag has a most important influence upon the rate of gas-oxidation.

7. *The Function of Ferric Oxide in Gas-Oxidation—Reactions between Ferric Oxide and Silica.*—The oxidation of the slag is largely conditioned by the very important fact that at high temperatures Fe_2O_3, either free or when dissolved in a silicate melt, undergoes dissociation with the formation of FeO, oxygen being liberated. Pure Fe_2O_3 dissociated under atmospheric pressure at about 1,350 deg. C., and the new compound formed is stated to be magnetic.* In an experiment described below where a scale containing 23 per cent. of Fe_2O_3 was heated well above its melting point in the gases of an oxygen furnace, the melt was found to contain 17 per cent. Fe_2O_3. It may, therefore, be concluded that the melts derived from Fe_2O_3 form a series with varying contents of this substance, the proportions obtained depending on the temperature and on the oxidising power of the gases.

When silica is also present in the melts the equilibrium between the two oxides of iron under a given gas will in general be altered to an extent dependent on the silica content. The existence of such a relationship has recently been indicated by McCance,† as the result of

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* A. McWilliam and W. H. Hatfield, Journal of the Iron and Steel Institute, 1904, No. II, p. 216.

† J. E. Stead, Proceedings of the Cleveland Institution of Engineers, 1913,–14, p. 195.

* Journal of the West of Scotland Iron and Steel Institute, vol. xx. p. 138.

† The weight given is the available Fe_2O_3 content of the ore used; slight corrections necessary, owing to the presence of a little silica in the ore, have been omitted. It is assumed that the carbon, silicon, and manganese were respectively oxidised to CO, SiO_2, and MnO, and that no silica was absorbed from the bottom and banks after melting. If the last action occurred to any extent more ore would be used in forming slag, thus leaving even less oxygen available for the removal of the metalloids.

‡ So far as an appreciable amount of oxygen was present in the metal as FeO when lime was first added, and was removed during the period considered, a small reduction in this quantity will be necessary.

* J. Walden, American Chemical Society, 1908, vol. xxx, p. 1,350.

† *Loc. cit.*

the examination of mill cinders. If a comparable series is to be obtained by this means, it is necessary that all the samples should be taken from furnaces working under the same conditions as regards gas and temperature. The following series taken from mill soaking pits where the conditions were very fairly constant affords a good illustration of the influence of silica on the equilibrium between ferrous and ferric oxides :—

—	SiO_2.	FeO.	Fe_2O_3.
	per cent.	per cent.	per cent.
1	7·8	63·1	26·5
2	22·6	56·8	15·7
3	32·0	57·8	7·1
4	34·8	57·1	6·0

In order to obtain further evidence on this question, series of experiments were made in which samples of mill scale containing about 25 per cent. of Fe_2O_3 were mixed with varying amounts of silica and heated in an oxygen furnace. Melts of about 25 grammes and about ¼ in. deep were made in uncovered platinum crucibles, and so were exposed to the burnt gases. In both series the pressure of oxygen and gas used were kept constant throughout, and the furnace was allowed to become thoroughly hot before the first sample was put in. The order in which the mixtures were melted was varied in order to guard against any errors which might arise owing to a gradual increase in the furnace temperature during the experiments. Each melt when withdrawn from the furnace was rapidly cooled under water so as to avoid, as far as possible, oxidation by the air while cooling. In both series the period of heating given was ten minutes after complete fusion had occurred ; experiments made both with shorter and longer periods indicated that this time was approximately sufficient for the establishment of equilibrium with the gases. In the first series the temperature was about 1,400 deg. C. and the following results were obtained :—

—	SiO_2.	FeO.	Fe_2O_3.	FeO/Fe_2O_3
	per cent.	per cent.	per cent.	
1	—	85·4	13·5	6·3
2	15·0	77·0	7·5	10·3
3	25·0	66·8	6·9	9·7
4	35·0	60·4	3·1	19·5

The second series was made at a somewhat higher temperature, more oxygen and gas being used. The results are given below :—

—	SiO_2.	FeO.	Fe_2O_3.	FeO/Fe_2O_3
	per cent.	per cent.	per cent.	
1	—	80·7	17·5	4·6
2	15·0	69·8	13·4	5·2
3	25·0	62·5	10·8	5·8
4	35·0	58·9	4·8	12·3

The results of the above series are plotted in a triangular diagram (Fig. 3, page 853), in which the three variables are FeO, Fe_2O_3, and SiO_2. The three lines so obtained converge toward a point on the SiO_2—FeO line at about 57 per cent. FeO. The experimental data show that after a certain point the addition of silica exercises a very strongly marked action in reducing the amount of Fe_2O_3 present. Further work on this interesting and important system is greatly needed.

The shape of these curves is not consistent with the assumption that the silica acts simply as a diluent, and the explanation of the rapid diminution of the Fe_2O_3 must be sought in the constitution of the melted silicates. In view the of Vogt, "The silicate melts are crystalloid reciprocal solutions of stoichiometric compounds ; namely, of those compounds which crystallise out upon sufficient cooling." This expression must be taken to include also molecules which do not happen to crystallise out on freezing, but which might do so if present in sufficient amount ; thus it cannot be presumed that the rhodonite molecule is absent from the melts on the left side of (Fig. 1, page 853), although solid rhodonite does not separate until manganese is present in larger proportion. Reactions such as that under consideration offer an independent means of investigating the chemical constitution of melts containing FeO. The shape of the curves given in Fig. 3 would seem to indicate that FeO forms a stable silicate molecule which is oxidised with more difficulty than the free oxide. It will be shown later that ferrous silicate melts are also difficult to reduce.

In the investigation of the reactions between slags and gases it will be necessary to consider the solubility of the gases in the melts. Analyses made at the instance of Sir I. Lowthian Bell * showed that the gases evolved from blast-furnace slags in cooling have a composition generally resembling that of the furnace gases. The presence of dissolved gases in ordinary acid slags is proved by the porosity which they occasion in the centre of the slag-ball. In the experimental melts just described, the presence of dissolved gases was clearly shown, especially in those melts which contained 15 per cent. and 25 per cent. of silica ; after the surface layer had crystallised, the evolution of gas from the interior caused the expulsion of some underlying molten slag which flowed over the surface. It would seem that the gas solubility may vary according to the acidity, and perhaps the nature of the bases present.

8. *The Ferric Oxide Content of the Slag during the Process.*—The experimental evidence just given clearly shows that the maximum amount of ferric oxide which can be present in an acid slag at any period will depend upon the temperature, composition of the slag, and oxidising character of the gases passing through the furnace. The equilibrium composition of such a melt in contact with an oxidising atmosphere is reached by a fairly rapid reaction, and in all probability the amount of ferric oxide in the ordinary slag under working conditions can never exceed 4·0 per cent. This limiting quantity will only be attained in the absence of reduction by metal or gas. The analysis of acid slags taken at various stages of the "boil" invariably shows that the content of Fe_2O_3 is much lower than the above figure—in fact, it seldom exceeds 0·4 per cent. ; the accumulation of this compound in the slag during this period must inevitably be prevented by the reducing action of the metallic globules and possibly by the presence of CO. It might be supposed that the Fe_2O_3 content of the slag would be raised for a time by the addition of a large quantity of Fe_2O_3 (as ore) to the bath. This was not found to be the case ; the quantities of the two oxides of iron in samples of slag taken immediately before and after the addition of 10 cwt. of purple-ore bricks are given below :—

	Per Cent.	Per Cent.
Before ore addition ...	FeO 26·7	Fe_2O_3 0·30
After ore addition ...	FeO 33·7	Fe_2O_3 0·30

On the amount of slag present the maximum increase of Fe_2O_3 should have been 8·5 per cent., but this has here appeared as FeO. In the above instance the furnace had settled on the "boil," the carbon being about 1·50 per cent. When a similar addition is made at an earlier stage it frequently causes no increase or iron, either ferrous or ferric, in the slag. The condition of the bath before boiling is such that probably no defined line of separation exists between metal and slag ; the rapid reduction of ore at this stage is no doubt due to the powerful action of the silicon which is being removed from the metal.

Experiments such as the above clearly show that Fe_2O_3 is very rapidly destroyed in the slag by the reducing actions. At the temperature of the furnace, even in the absence of reducing agents, any excess of Fe_2O_3 added as ore must be rapidly decomposed by means of the reaction with silica, described in the preceding section ; this decomposition could, however, only proceed as far as the equilibrium content, which appears to be about 4·0 per cent. The fact that the actual amount retained is far below this must be regarded as conclusive proof that Fe_2O_3 in the acid slag is extremely active as an oxidising agent. The rapidity with which Fe_2O_3 is destroyed makes it seem possible that during a heavy feed of ore, an appreciable quantity of free oxygen may be liberated.

The amount of Fe_2O_3 in the slag is constantly being raised by the absorption of oxygen at the upper surface, owing to the tendency of the slag to reach equilibrium with the gas. Through the circulation of the slag and the movement of the metallic globules contained in it, the newly formed Fe_2O_3 is continually being brought into contact with the metal, by which it is quickly destroyed. Thus the Fe_2O_3, although present in such small amount, must play an important part in the gas-oxidation.

Direct evidence of the constant formation of Fe_2O_3 can be obtained in the finishing period when the carbon has diminished to below 0·30 per cent. At this stage the volume of CO passing through the slag is greatly lessened, and the metallic globules are no longer held in suspension in any quantity. As a consequence the Fe_2O_3 is not reduced as rapidly as it is formed, and the amount present begins slowly to increase, more especially in slags not containing lime, and this causes the colour of the quickly cooled slag to become gradually darker. The following example, showing the increase in Fe_2O_3 in a series of samples taken during a period of about one hour, will serve to illustrate this effect :—

	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon in metal ..	0·28	0·24	0·20	0·14
Fe_2O_3 in slag	0·20	0·28	0·85	1·71

The highest amount yet found in a finishing slag was about 3·0 per cent. This increase can obviously be attributed to the diminution of the carbon content of the bath and consequent slackening of the reducing actions. The darkening in colour of the quickly cooled slag sample caused by the rise in Fe_2O_3 affords the smelter a very useful indication of the condition of the bath as regards its carbon content.

9. *Reactions between Metal and Slag.*—The number of possible reactions by which the carbon of the metal may be removed by the slag is considerable. Those in which CO_2 is a product in all probability play a very subordinate part, however, and for the present purpose it will be sufficient to consider only the three reactions in which CO is produced. These are given below, together with a fourth reaction, in which metallic iron is oxidised by its higher oxide :—

(1) $FeO + C = CO + Fe$.
(2) $Fe_2O_3 + 3C = 3CO + 2Fe$.
(3) $Fe_2O_3 + C = CO + 2FeO$.
(4) $Fe_2O_3 + Fe = 3FeO$.

The complete determination of the relative velocities of these reactions in the furnace is not yet possible, but certain general conclusions may be drawn from the changes in the slag analyses at the finishing stages. The above reactions differ in their effect on the total iron content of the slag ; No. 3 causes practically no change ; Nos. 1 and 2 lower the iron, while No. 4 is the only reaction possible by which the percentage of iron can be increased. In the later stages of the process, when the carbon has fallen below 0·15 per cent., the iron content of the slag, after being stationary for a time, may actually rise, as shown below, without any further ore addition being made :—

Time.	10.45 a.m.	11.0 a.m.	11.20 a.m.	11.40 a.m.
	per cent.	per cent.	per cent.	per cent.
Carbon in bath ..	0·14	0·12	0·10	0·08
Iron in slag ..	26·3	26·3	27·0	27·6
Ferrous oxide in slag ..	32·5	32·3	32·6	33·2
Ferric oxide in slag ..	1·45	1·7	2·1	2·57

This increase must be due to the predominance of reaction (4) over reactions (1) and (2), while the constancy attained previously was due to a balance, the total rates of (1) and (2) at this period being closely equal to that of (4). There can be little doubt that during the "boil" reaction (4) between the molten iron and the ferric oxide still occurs, but is masked by the greater speed of the carbon reactions (1) and (2), the net result being a diminution of the FeO in the slag. It should be remarked here that the variation in the area of reacting surface, due to the presence or absence of metallic globules in the slag, will affect all the reactions equally, so that their relative rates will not be disturbed from this cause.

It is of interest to note that reaction (4) also occurs when solid iron is present in a melt containing Fe_2O_3. About 20 grammes of mill cinder (30 per cent. SiO_2) was placed in a platinum crucible and melted in an oxygen furnace. A piece of pure iron weighing 1·40 gramme was then quickly pushed beneath the surface, and the heating continued at about 1,400 deg. C. for fifteen minutes, after which time the melt was rapidly cooled. On crushing, no trace of the metallic iron could be found, and the iron content of the cinder had increased from 47·2 per cent. to 49 per cent. There can be no doubt that this reaction plays an important part in the formation of scale on the surfaces of ingots, slabs, &c., when in the soaking pits.

The oxidation of the carbon by the slag takes place by reactions (1), (2) and (3). The first depends upon the concentration of the FeO, while the other two will depend upon that of the Fe_2O_3. See that in the proportion of the former oxide to the latter is general greater than 100 to 1, and even at the end of the process is usually more than 10 to 1, it is evident that if any considerable part of the oxidation is performed by the Fe_2O_3 the rate of reaction (1) must be very much less than that of (2) and (3). A strong reason has already been given for believing that this is the case, for on addition of Fe_2O_3 to the bath this oxide is at once destroyed, while the FeO increases. Several other considerations can be advanced which all point to the conclusion that the greater part of the carbon oxidised by the slag is removed by the Fe_2O_3,* according to equations (2) and (3), and only a small part by the FeO, according to equation (1).

(*a*) Percy † endeavoured to reduce a melt of fayalite composition by carbon, and only succeeded in obtaining a melt having a similar composition to a ferruginous acid slag. He was unable to effect the complete reduction of FeO in the presence of excess silica.

(*b*) It is well known that during the "boil" the thickening of the slag through removal of the FeO is accelerated by the action of a good flame on the surface. This may well be connected with the more rapid oxidation of the FeO in the slag through the action of the hot flame, the Fe_2O_3 so formed being then reduced to metallic iron by the carbon.

(*c*) In a series of interesting experiments, Hatfield and McWilliam ‡ found that a considerable reduction of silica could be obtained under suitable conditions even in the presence of 21·0 per cent. of FeO. Had it been possible to reduce the FeO rapidly, this should have occurred in preference to the reduction of silica.

(*d*) The great difficulty with which FeO is reduced in a siliceous slag is very well shown in the above-mentioned experiments, in which a furnace was held for over two hours without ore additions, the slag becoming very thick. During this time the carbon dropped from 0·86 per cent. to 0·38 per cent., while the FeO in the slag was only lowered from 24 per cent. to 20·8 per cent. Thus, although the slag was in contact with a metal fairly rich in carbon, no great loss of FeO had occurred, most of the carbon having been eliminated by gas-oxidation. Similar results have been obtained by the authors.

These considerations all indicate that in the presence of a high silica content, such as occurs in the acid slags, the reduction of the FeO is very slow, so that the amount of carbon removed by reaction (1) is comparatively small. It follows that if a charge covered with an ordinary slag could be held in a neutral atmosphere the slag would thicken only very slowly and the elimination of the carbon would be greatly retarded. This effect may possibly be due to the existence of a stable silicate of iron in the molten slag. That the oxidation of the carbon by the slag during the "boil" is rapid is evident from the manner in which the slag quickly thickens after a feed of ore. As the reduction of FeO appears to be so slow, this rapid removal of iron must be attributed to the complete reduction of Fe_2O_3 formed from the FeO by gas-oxidation ; the ferrous

* "The Manufacture of Iron and Steel," 1884.

* The possibility that Fe_2O_3 may play an important part as a carrier of oxygen was first suggested by Dr. Stead. Journal of the Iron and Steel Institute, 1897, No. I, p. 134.

† W. H. Greenwood, "Steel and Iron," 1893, p. 56. See also discussion by H. Louis on Paul's paper, Journal of the Iron and Steel Institute, 1912, No. II, p. 105.

‡ Journal of the Iron and Steel Institute, 1902, No. I, pp. 54-62.

silicate must be oxidised before it can be easily reduced to form metallic iron. It is thus clear that the rapid working of the charge is dependent to a large extent on the degree to which gas-oxidation occurs. The use of a rich gas with as much air as the furnace can carry will afford the best conditions for the rapid thickening of the slag, so permitting an increased frequency of ore additions which will accelerate the removal of the carbon.

10. *Oxidation by Direct Contact of Metal with Gas.*—The preceding remarks have been concerned entirely with the transmission of oxygen to the metal by way of the slag. During the "boil," however, the slag is highly charged with metallic iron, and the possibility of oxidation by direct contact of metal with gas must also be considered. That gas-oxidation actually does occur by this means is clearly seen by comparing the rate at which oxygen is absorbed from the gas during the boiling period (1) with that during the finishing period (2).

(1) It has already been shown (p. 858) that more than 50 per cent. of the carbon present on melting is removed during the subsequent working by gas-oxidation. This figure includes the amount eliminated in the finishing period when the slag is practically free from metal, but since the quantity of carbon removed in the later stage is relatively small the same ratio of gas-oxidation may be held to apply to the boiling period taken by itself, and the rate of removal of carbon by this means will be about 0·30 per cent. per hour.

(2) As soon as the metal has dropped off the "boil" the metallic globules are no longer held in suspension, and oxygen from the gas can then only reach the metal through the slag. The amount of oxygen taken from the gas at this stage may readily be calculated from analyses of slag and metal sample; the following will serve as an illustration. The last feed of ore was given to a 100-ton charge when the carbon was about 0·28 per cent. After the reaction had subsided samples of metal and slag were taken at intervals until the carbon had been reduced to 0·12 per cent. The results of the analysis of these samples are given in the table below :—

Time	11.5 a.m.	11.15 a.m.	11.27 a.m.	11.45 a.m.	12.0 a.m.
	per cent.	per cent.	per cent.	per cent.	per cent.
Carbon in metal ..	0·24	0·22	0·19	0·15	0·12
Ferrous oxide in slag ..	31·2	30·90	30·50	29·4	29·3
Ferric oxide in slag ..	0·35	0·30	0·55	0·60	0·85

The finishing slag weighed about 12 tons, and had the following analyses: SiO_2, 54·3 per cent.; FeO, 29·3 per cent.; MnO, 10·10 per cent.; CaO, 3·4 per cent.; MgO, 0·80 per cent. From these figures the amount of oxygen taken up can be obtained as follows :—

(1) In the formation of Fe_2O_3 in slag about	0·018
(2) In the elimination of 0·12 per cent. carbon	0·160
Total	0·178

From this total 0·055 ton must be deducted, owing to removal of FeO from the slag. The amount of oxygen absorbed in 55 minutes by gas oxidation was, therefore, 0·123 ton, which would be sufficient to remove 0·10 per cent. of carbon per hour, while during the boiling period the average drop in carbon exceeded 0·50 per cent. per hour, of which about 0·30 per cent. per hour was removed by gas-oxidation. It is probable that the figure found for the end period is on the low side, owing to the comparative quietude of the slag, the lower content of FeO and higher content of Fe_2O_3, which would all tend to reduce the rate of absorption. Even when all possible allowance is made for such points as these, and for a probable small increase of FeO in the metal, it seems certain that the amount of gas-oxidation occurring during the "boil" was at least twice as much as that in the finishing stage, and as the area of the bath and the average composition of the slag remained about the same throughout, the greater rate during the "boil" must have been caused by the direct contact of the metal with the gas. This contact is effected in two ways :—

1. The violent agitation, brought about by the addition of large lumps of ore, often causes quantities of metal momentarily to flow over the surface of the slag.

2. A still more important action must be due to the very numerous globules of metal which are constantly entering the surface layer of the slag, where they will be rapidly oxidised, even if they do not actually come into open contact with the gas.

11. *The Effect of Lime Additions on the Rate of Gas-Oxidation.*—It is well known that the presence of a considerable amount of lime in the slag retards the rate of removal of the carbon, especially in the finishing stages. As has just been shown, the oxidation of the carbon, after the metal has dropped off the "boil," takes place by way of the slag and not by direct contact; since the activity of the metal in reducing the slag is not affected by lime additions, the retardation must be attributed to a diminished capacity of the slag for absorbing oxygen. This view would require that, under equal conditions, a limey slag should contain a lower amount of Fe_2O_3 than one not containing lime. The following two analyses of finishing slags, which were obtained under comparable conditions, show that this is indeed the case :—

	C in Bath.	SiO_2.	FeO.	MnO.	CaO.	Fe_2O_3
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
1	0·13	52·8	30·1	10·2	0·8	1·70
2	0·12	50·6	21·9	10·5	13·8	0·30

It is clear that the diminution of the Fe_2O_3 content in No. 2 sample cannot be due simply to the lower content of FeO; the capacity of the slag for absorbing oxygen has evidently decreased independently of this. Slags of intermediate lime content are generally intermediate in their Fe_2O_3 content when taken at the same stage as above; an example is to be seen in the slag analysis given on page 858. The diminution of the Fe_2O_3 content in the presence of lime corresponds with the reduced oxidising power of these slags. Not only is the carbon removed more slowly, but the oxidation of the iron according to reaction (4) p. 859 is also greatly retarded. This is indicated by the fact that the increase in total iron which may occur in ordinary slags at the finish through the above reaction is seldom, if ever, obtained when lime is used in any quantity.

The action of lime in suppressing the gas-oxidation of the slag is of great practical value in the production of that state of the bath known as the "dead melt." When a perfectly dead melt is obtained, the carbon content of the metal becomes nearly stationary, a condition in which it is clear that gas-oxidation has almost entirely ceased. According to the views here advanced, by suitable lime additions the rate of formation of Fe_2O_3 and consequently the rate of gas-oxidation, can be greatly retarded. In the absence of further ore additions this retardation leads to a gradual slackening of the reaction; as a consequence, the metallic globules fall from the slag and so oxidation by direct contact also ceases. An opportunity is thus given for the completion of those reactions occurring in the body of the metal which lead to the production of the dead melt.

Summary.

The paper is divided into three sections, dealing respectively with the microstructure of slags, the structure of the hearth, and the reactions occurring in the molten slag during the process.

Part I.—The Microstructure of Acid Slags.

1. The minerals present in slowly cooled acid slags without lime are tridymite, cristobalite, fayalite, and rhodonite; the last-named contains the bases in very nearly the same ratio as the melt. The silica minerals freeze first, but super-cooling always occurs to some extent. They are followed by fayalite or rhodonite, the silicate formed being determined by the ratio of iron oxide to manganese oxide; when this exceeds 73 : 27 fayalite is formed; in other cases, rhodonite. In slags containing more than about 8 per cent. of lime, an anorthic metasilicate of CaO, FeO, MnO, MgO is obtained, which has a brilliant cleavage, and gives rise to a marked acicular fracture in the slag.

2. The order of freezing of the minerals in a number of slags whose analyses are given is represented in a ternary diagram, which is approximately that for the system FeO–MnO–SiO_2. A qualitative diagram is also given to illustrate the binary system FeO–SiO_2.

3. Acid slags after being reheated for 18 hours at 1,300 deg. C. contain free tridymite, and resemble the furnace hearth in structure.

4. Spoon samples taken from the furnace are superficially oxidised to a depth which depends on the nature of the slag, and is least when the silica is high or when lime is present. The dull lustre of fractured glassy samples is due to minute particles of silica.

Part II.—The Acid Hearth.

5. A number of analyses show that the hearth contains only 70 per cent. of silica, although the sand used is required to contain at least 96 per cent.

6. Microsections show that the upper layer consists mainly of interlacing plates of tridymite with interstitial slag; in the lower and cooler parts the quartz grains are less altered. The penetration of slag extends down to a well-defined limit, usually in the brickwork. The relatively small depression of the freezing point of silica in the presence of impurities is no doubt an important factor in the stability of the hearth.

7. The effect of impurities in the sand is complex; apart from softening the bank, they give rise to caking and so prevent the absorption of the fluid slag on the bottom by the new sand—an action which is essential for the satisfactory repair of the hearth.

8. The amount of ferric oxide in the hearth is considerably lower than that in the surface layers. This may be due to reduction by CO or metal, and to reaction with the silica present.

Part III.—The Molten Slag.

9. The adjustment of the slag by the smelter to the required degree of viscosity, and the manner in which the iron content is reduced by lime additions, are described.

10. The proportion of carbon removed by gas-oxidation is estimated from experimental data for casts with and without lime additions. Between melting and tapping at least half the carbon is so oxidised, and this proportion is not greatly altered when lime is used.

11. The physical conditions under which the molten slag reacts are discussed, and it is shown that during the "boil" one-half per cent. of the metal is suspended as small globules in the slag, so that the reacting surface is greatly increased.

12. The view is advanced that gas-oxidation takes place—(1) By the formation and reduction of Fe_2O_3 in the slag; (2) by direct contact of the metal and gas.

13. Experiments are given to show that the proportion between ferrous oxides in a melt is determined by the silica content, the temperature and the nature of the gases. In acid slag under ordinary furnace conditions the maximum (in the absence of reduction by the metal) appears to be about 4 per cent.

14. Throughout the "boil" the content of Fe_2O_3 remains very low (0·3 per cent.), but may increase in the finishing period as far as 3·0 per cent. It is clear that the Fe_2O_3 must be very rapidly destroyed by the reducing action of the metal, which slackens as the carbon content falls and so permits the increase of Fe_2O_3 at the finish.

15. The relative rates of various possible reactions between slag and metal are discussed. The constancy of composition of the slag in the later stages is due to a balance between the oxidation of iron from the metal, and the reduction of iron from the slag by the carbon. In an acid slag the latter reaction probably takes place mainly through the direct reduction of Fe_2O_3 rather than by the reduction of ferrous silicate.

16. Of the carbon removed from the metal after melting, roughly one-half is removed by the ore, one-quarter by gas-oxidation through the slag, and one-quarter by direct contact between metal and gas.

17. The effect of lime in the slag is to lower the Fe_2O_3 content; this action is probably of great value in protecting the metal from oxidation during "dead melting."

Government Surplus War Stores.—The Parliamentary Secretary to the Ministry of Munitions, Mr. Kellaway, in answer to an inquiry in the House of Commons, states that 3,535 tons of black corrugated iron sheeting, 22-gauge and 24-gauge, of various lengths and widths, have been notified to the Surplus Government Property Disposal Board as available for disposal.

Gas Apparatus in Mines.—From the statistics on the use of gas apparatus in Prussian mines during the year 1917 (*Zeitschrift für Berg-, Hutten- und Salinenwesen*, 1918, No. 4, pages 215 to 238) we see that various apparatus were used in 253 cases, the numbers being slightly higher than in the year previous. Dräger apparatus, mostly of the helmet type, were still decidedly predominating; but hose apparatus (helmets and mouthpiece) or the Westphalian system, were coming up more and more, and apparatus of Stolze and of König were also in use. In 14 cases special attempts were made to save life in accidents due to explosions of firedamp, other explosions, fires and gas fires, bad ventilation, benzene vapours; the number of people saved or found dead was 90; in the methane explosions all the victims were dead. As regards the saving of property the work was more successful in these cases, as the apparatus enabled the rescuers to get nearer the source of the accident. Six people were killed and 5 injured while being engaged in rescue work, because they were unfamiliar with the apparatus or stumbled or knocked against something. Revival attempts were successful in 60 out of 130 cases in which 44 different apparatus were used; most of these apparatus were Dräger's pulmotors, the others being Brat apparatus, oxygen inhalers and inhabad apparatus. Restoration of life after electric shocks failed in all the 13 cases although both pulmotors and inhabad apparatus were tried alternately sometimes.

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No Tender will be considered if received at the County Hall, Spring Gardens, S.W. 1., after Four p.m., on Monday, 7th July, 1919.

The Council does not bind itself to accept any Tender, and reserves to itself the right to accept the whole or a portion of any Tender.

JAMES BIRD,
Clerk of the London County Council.
W 710

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Tenders enclosed in separate envelopes addressed to the CLERK OF THE BOARD, Metropolitan Water Board, South Place, Finsbury, E.C. 2, and endorsed "Tender for Hitham Reservoir," and "Tender for Farnborough Reservoir" respectively, must be delivered at the Offices of the Board not later than Ten a.m. on the 21st July, 1919.

A. B. PILLING,
Clerk of the Board.

2, South Place,
Finsbury, E.C. 2.
26th June, 1919. W 846

COUNTY OF WEST SUSSEX.

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E. SALTER DAVIES,
Director of Education.
16th June, 1919. W 715

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H. E. CURTIS,
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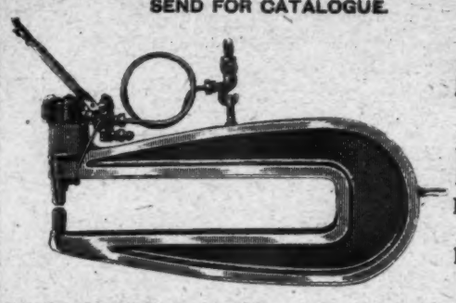
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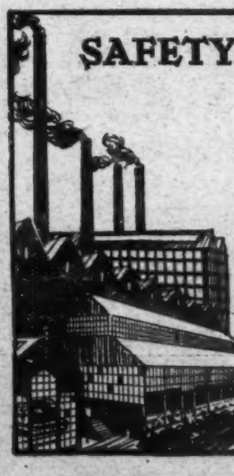
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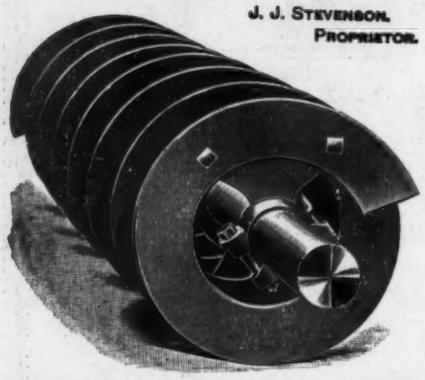

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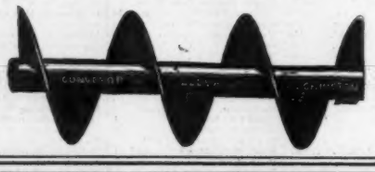

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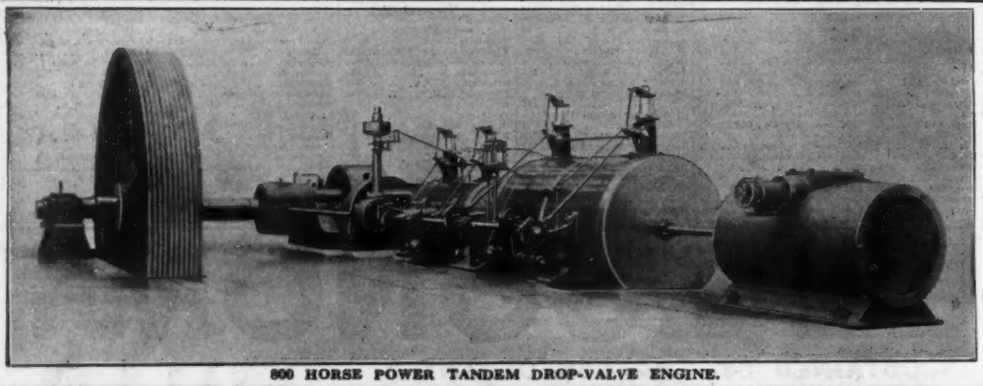

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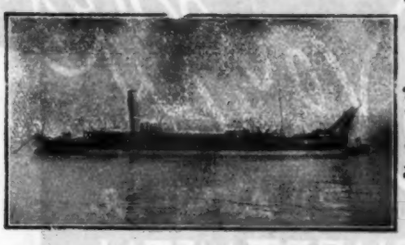

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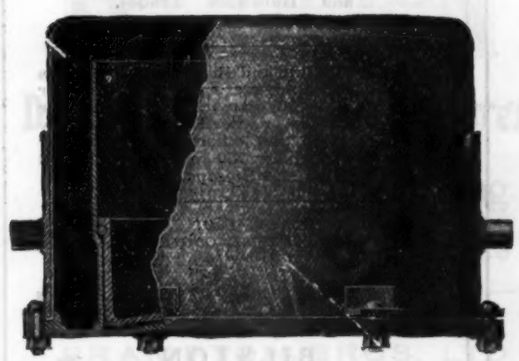

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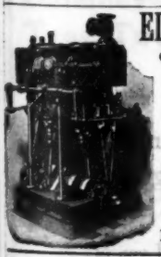

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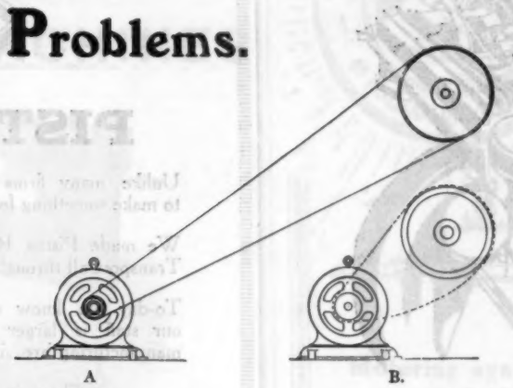

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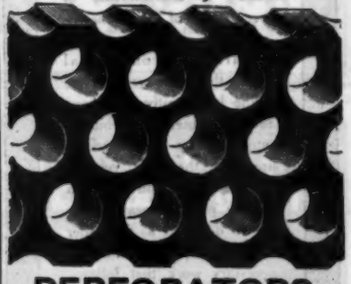

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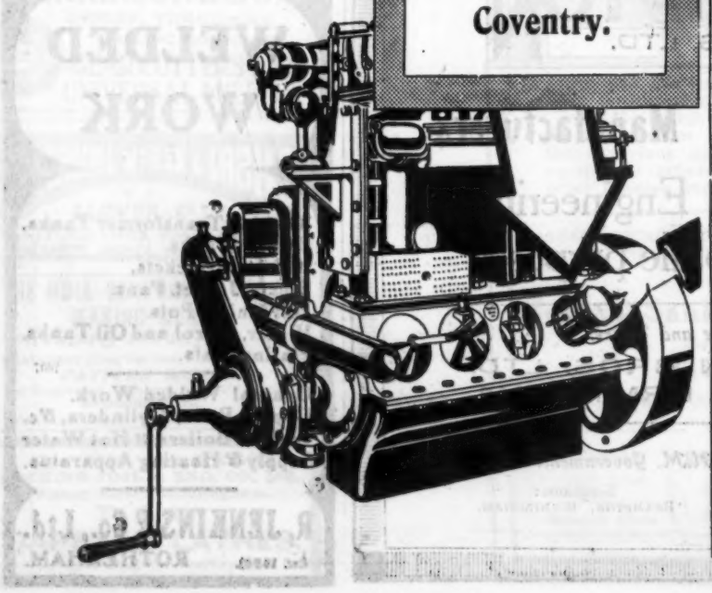

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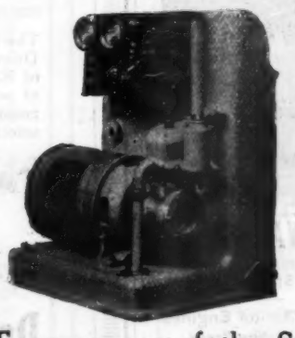

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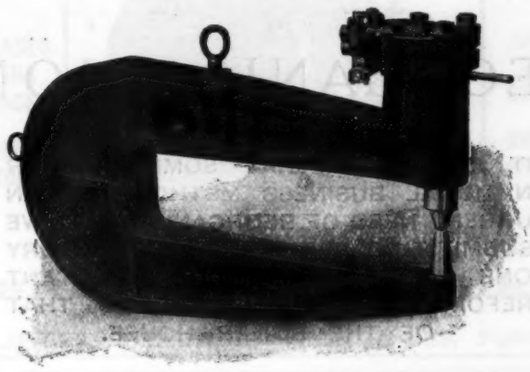

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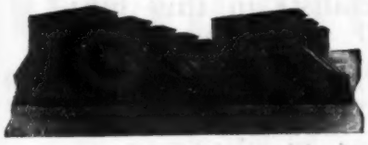

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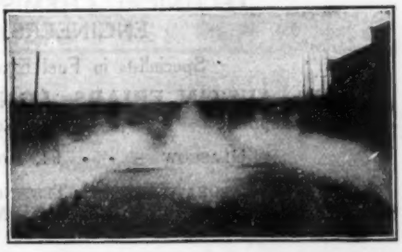

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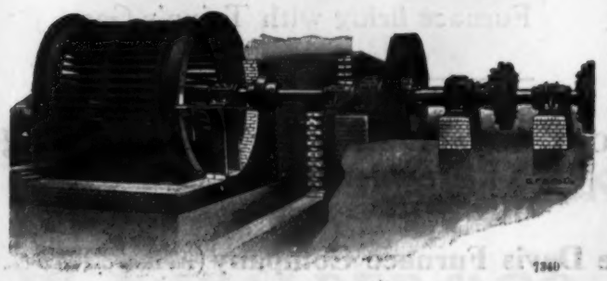

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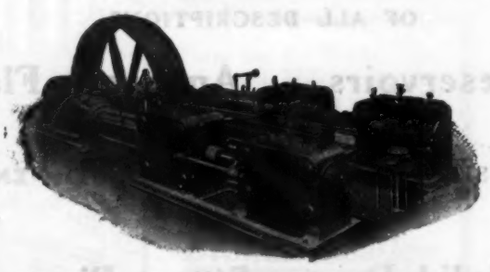

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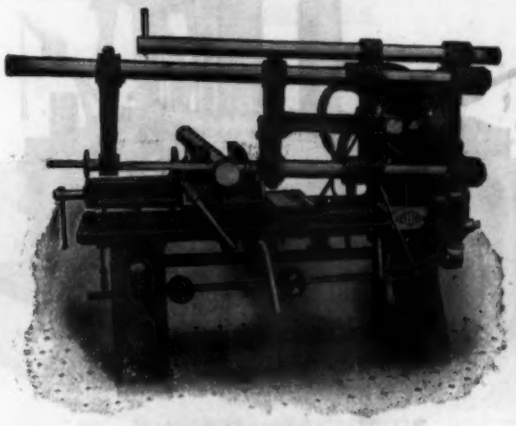

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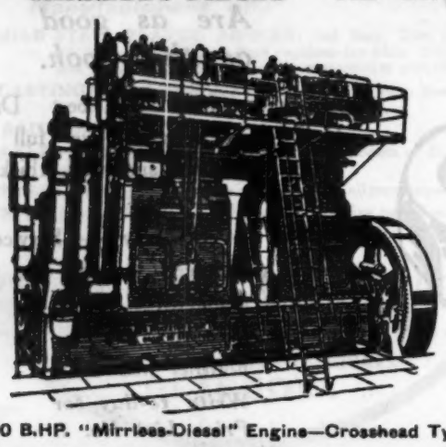

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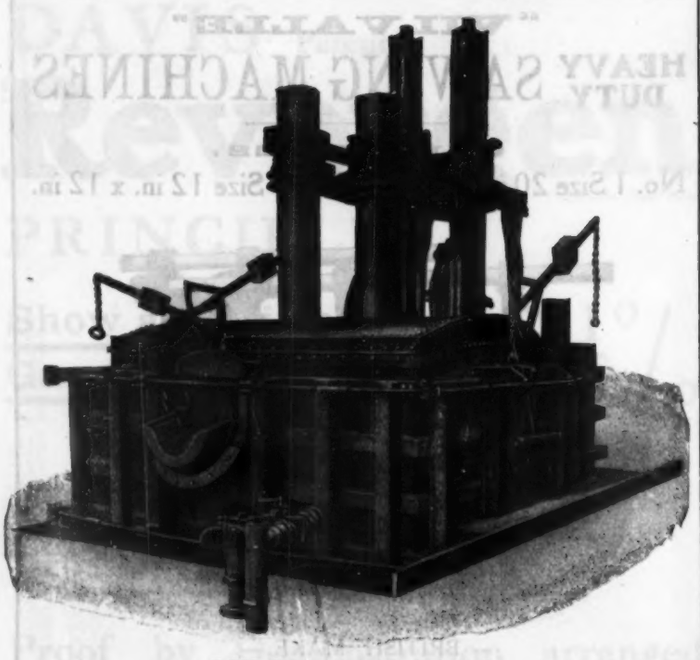

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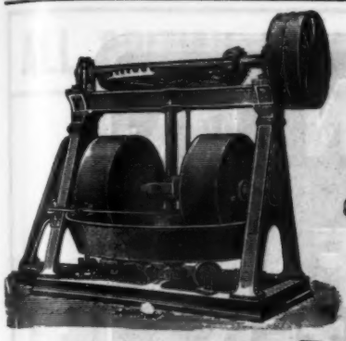

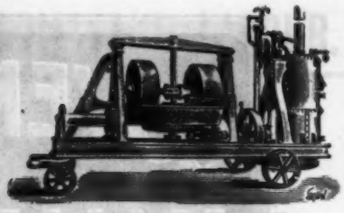

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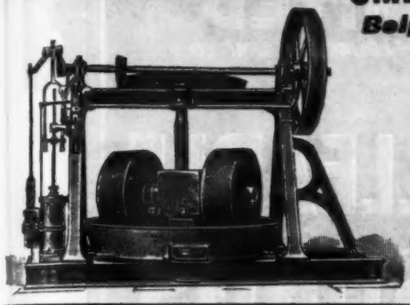

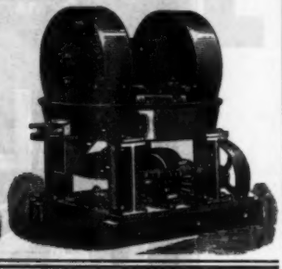

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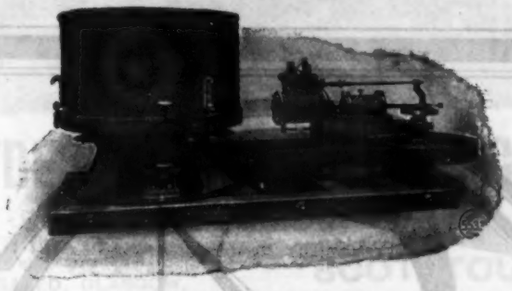

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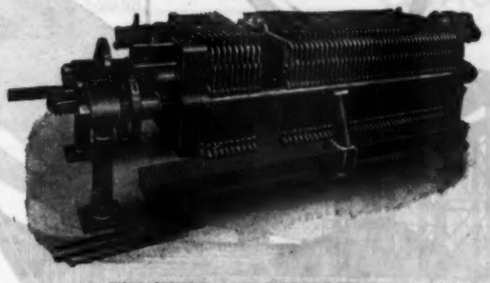

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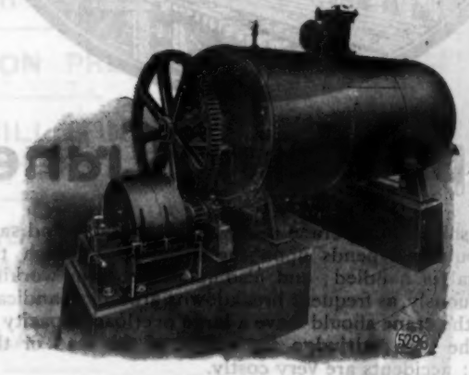

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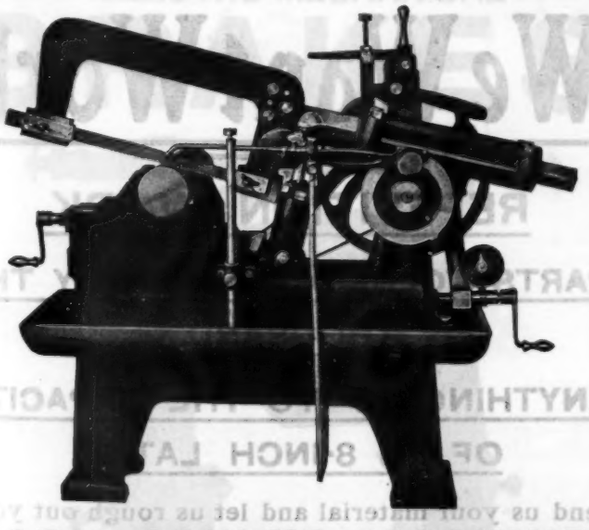

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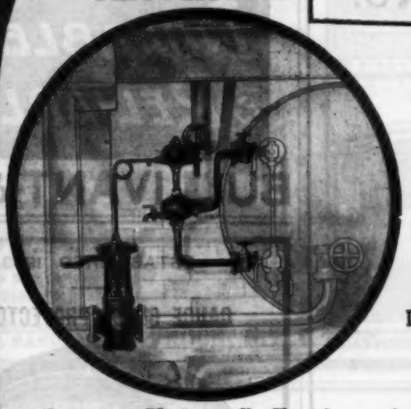

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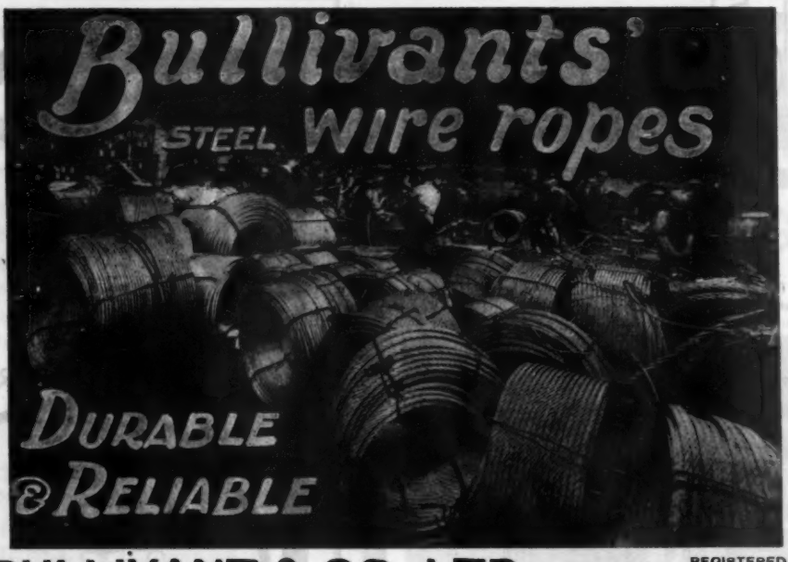

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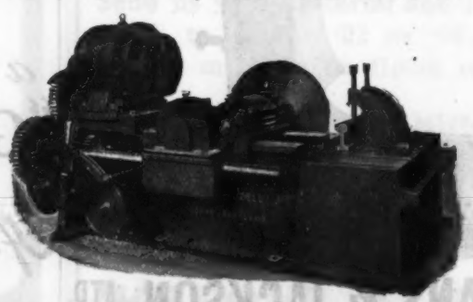

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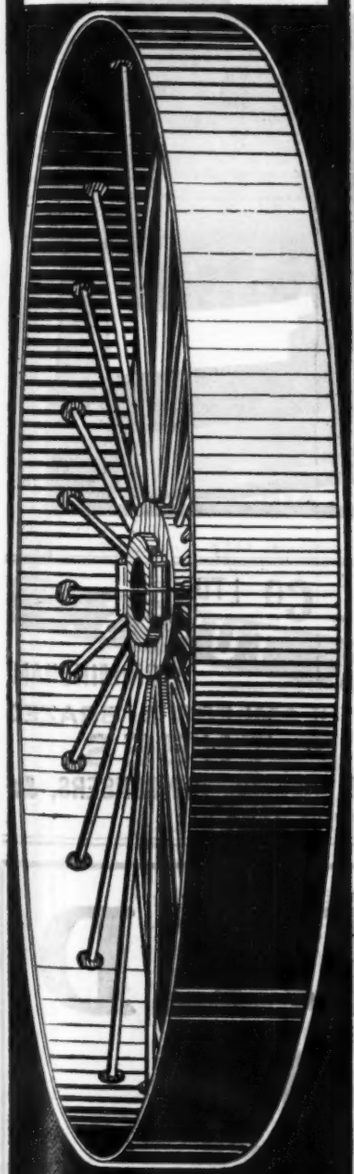

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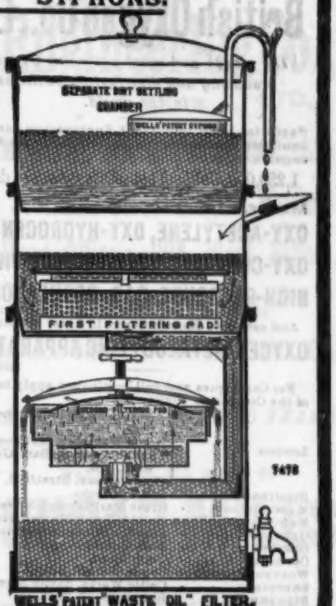

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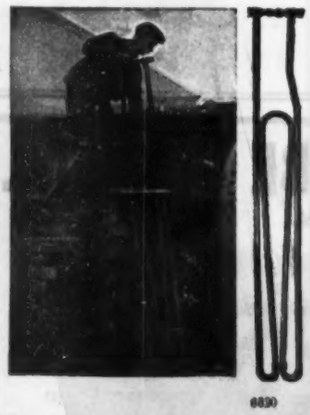

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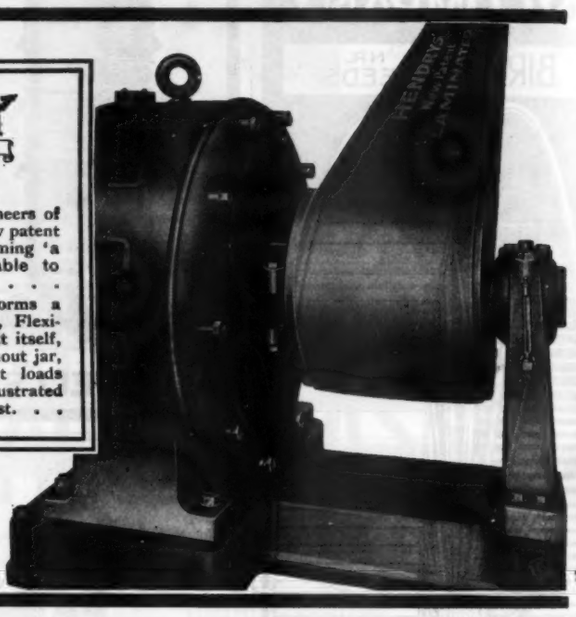

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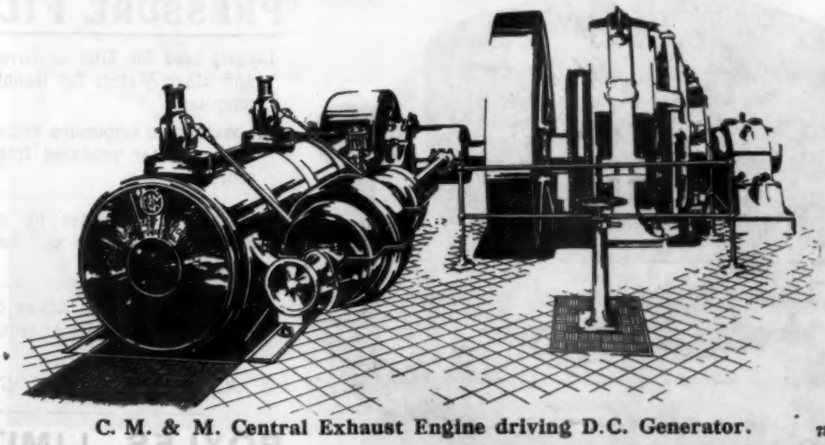

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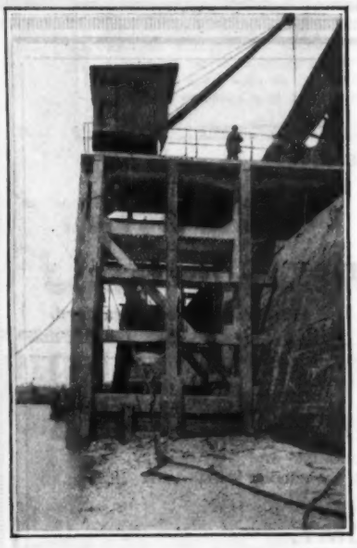

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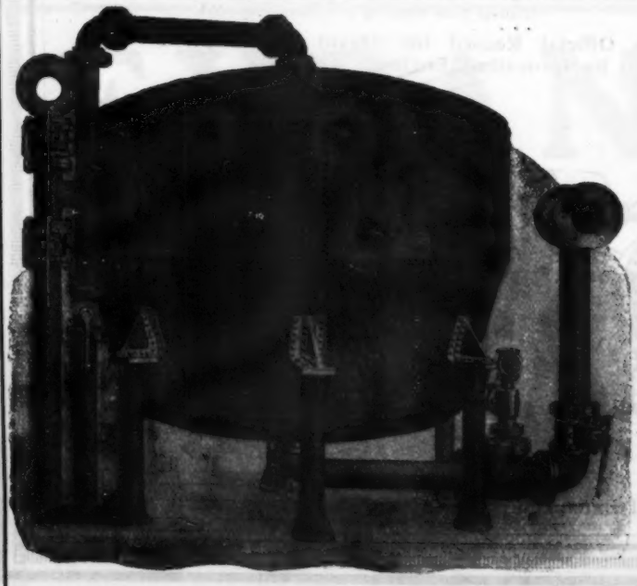

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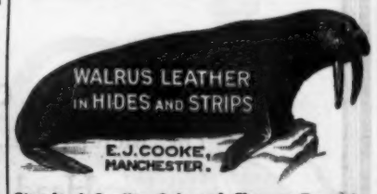

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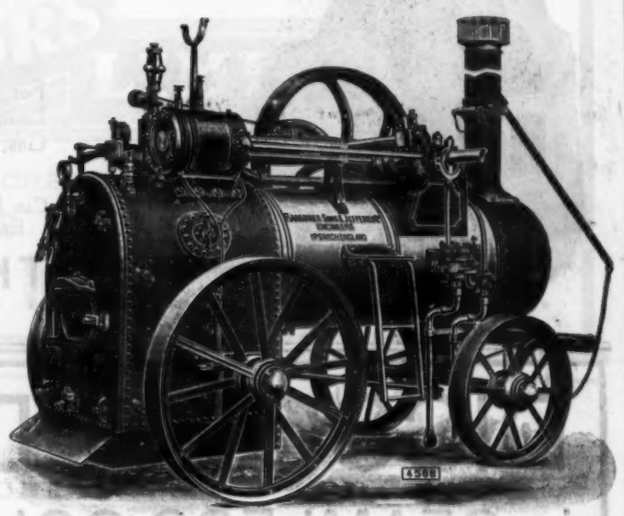

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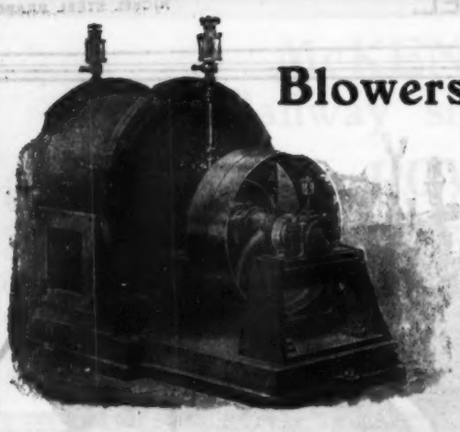

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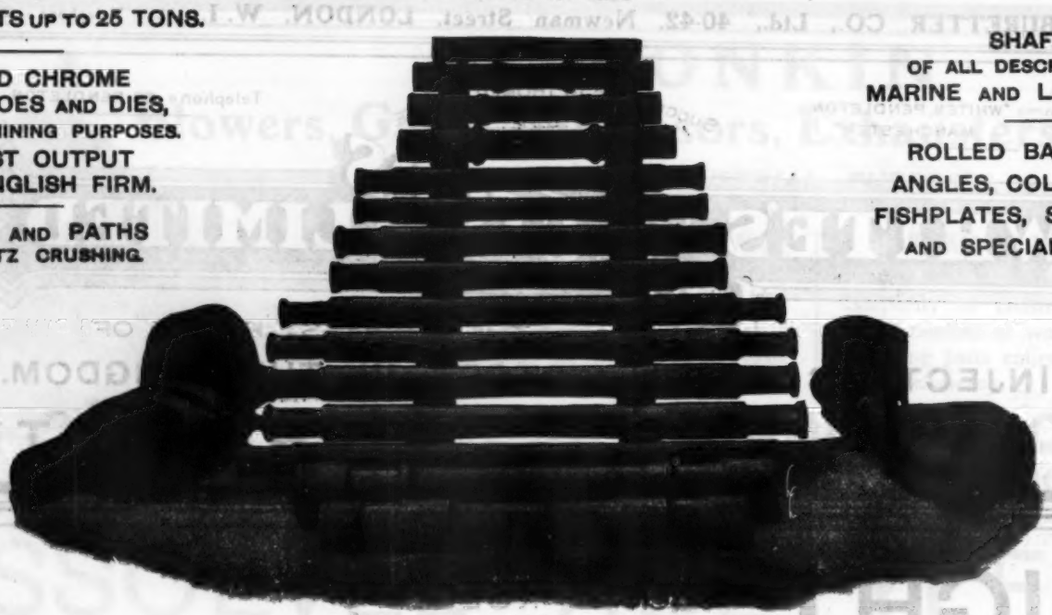

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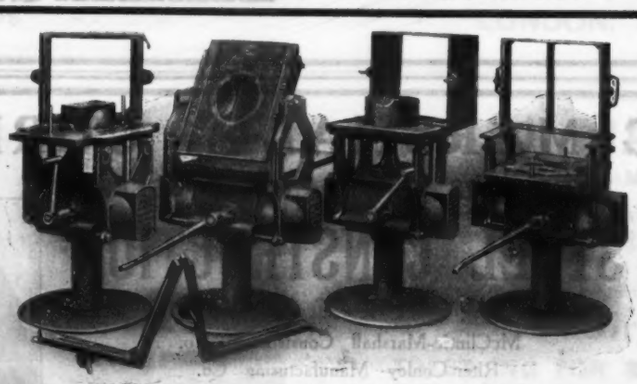

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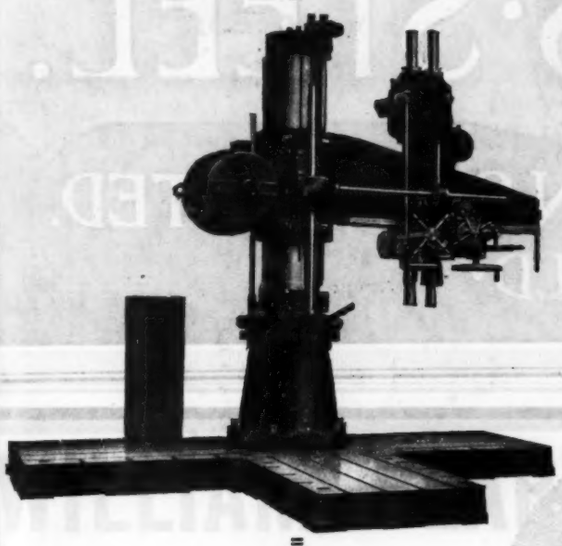

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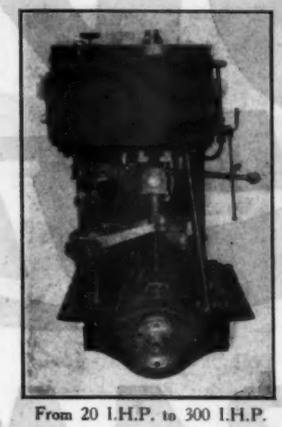

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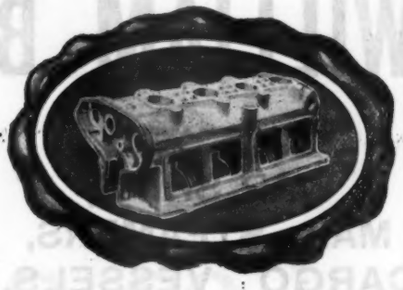

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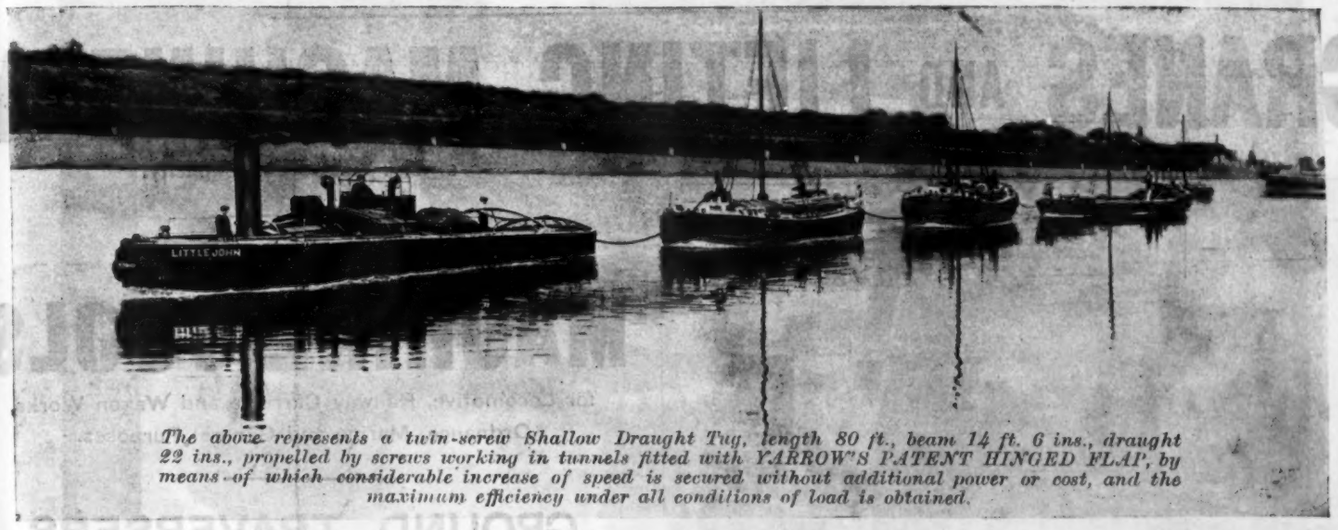

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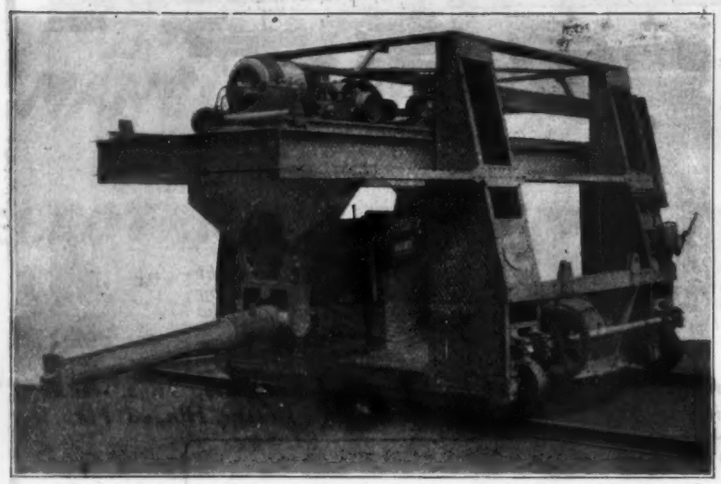

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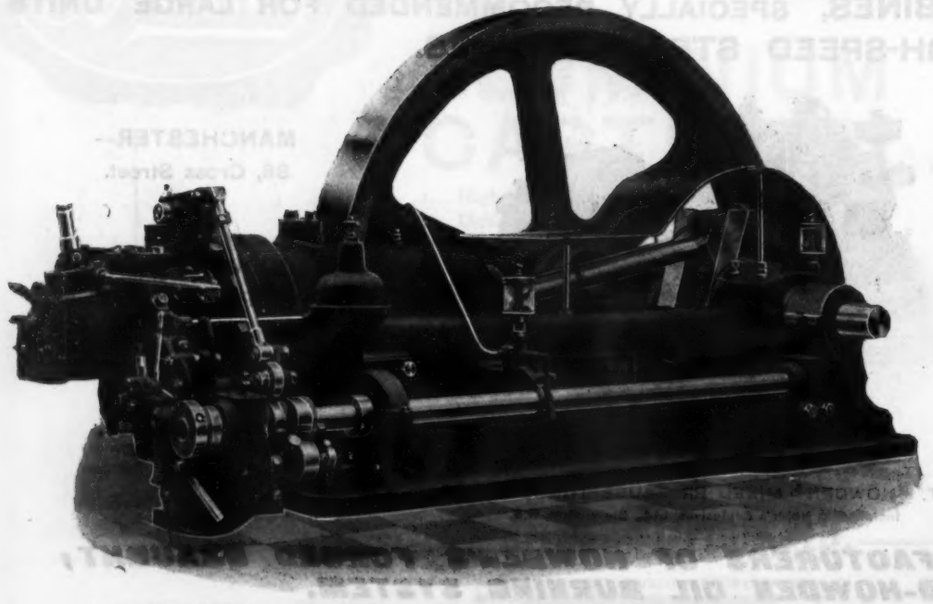

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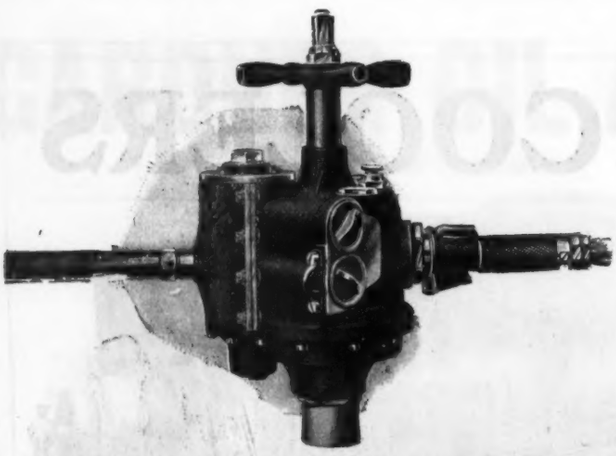

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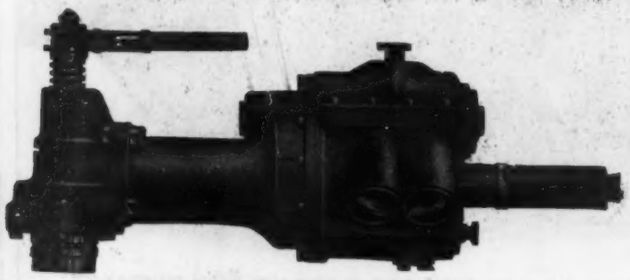

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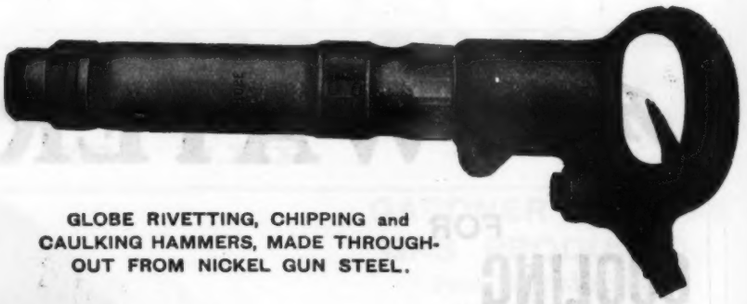

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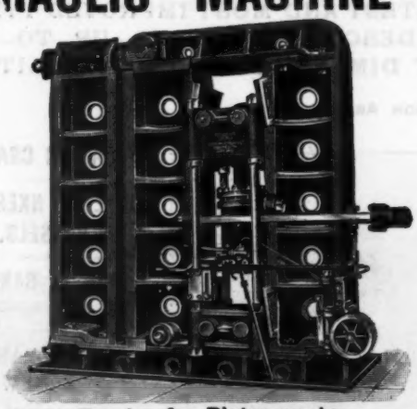

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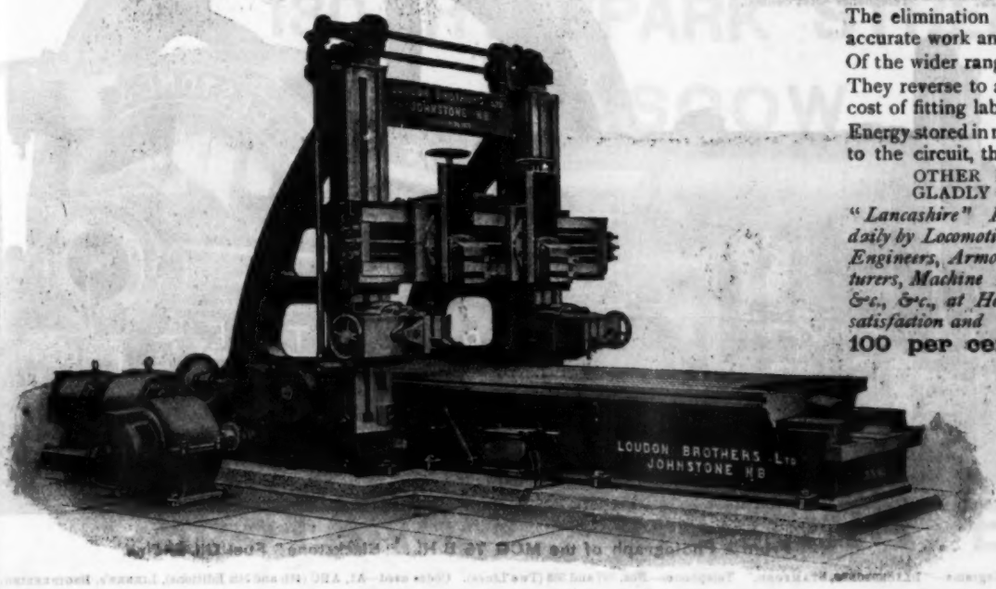

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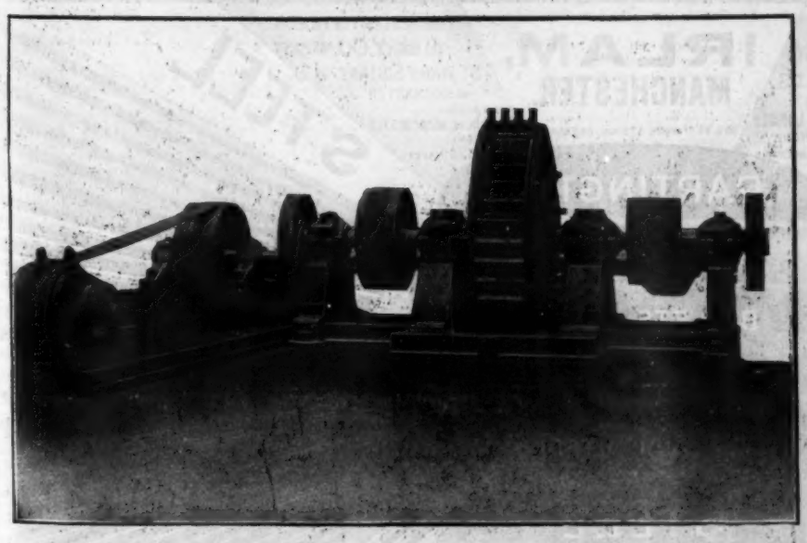

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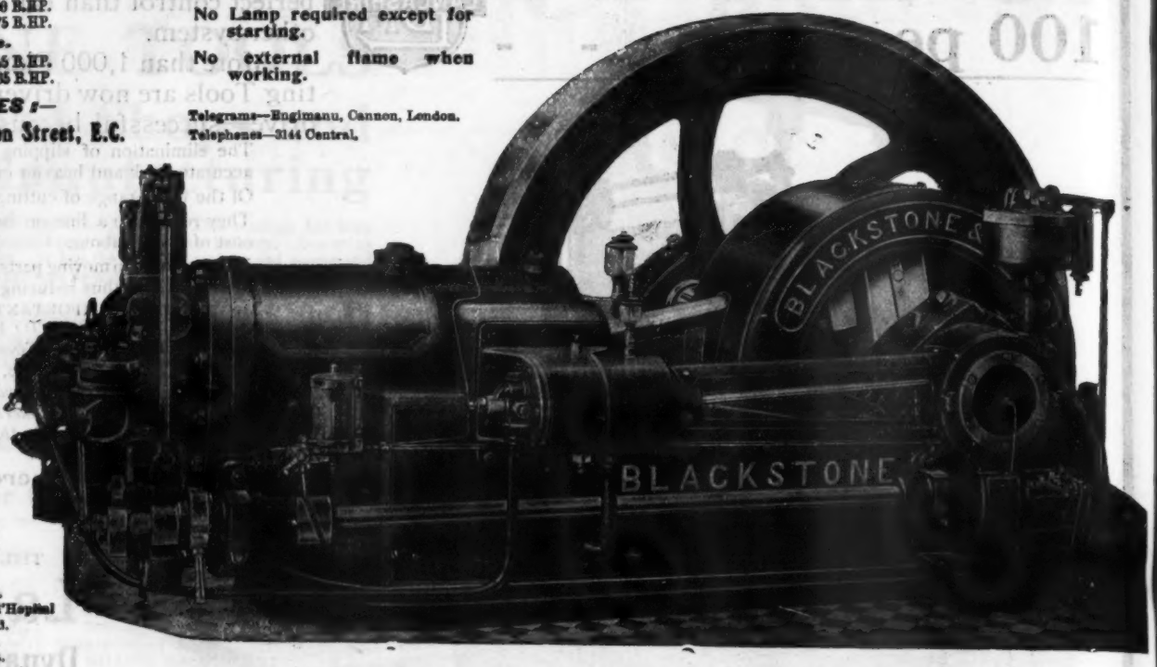

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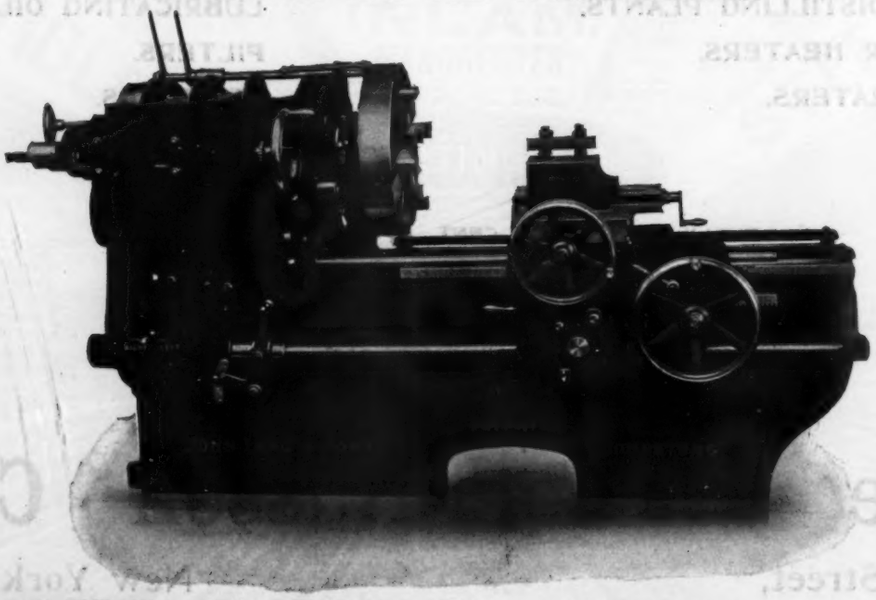

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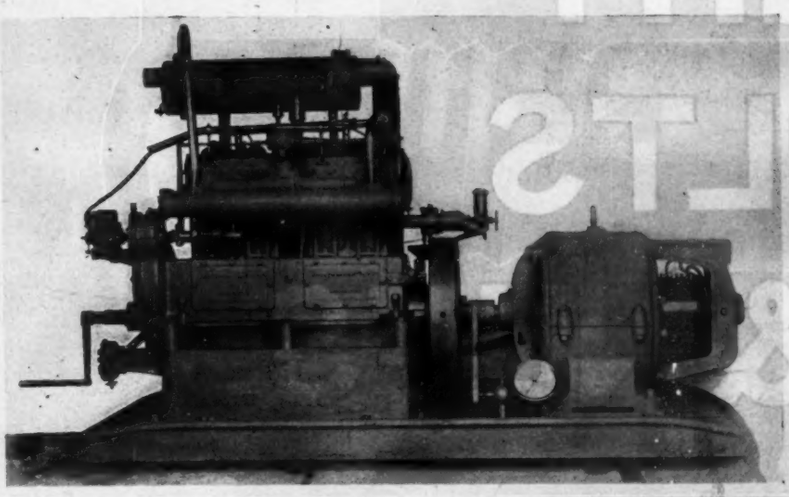

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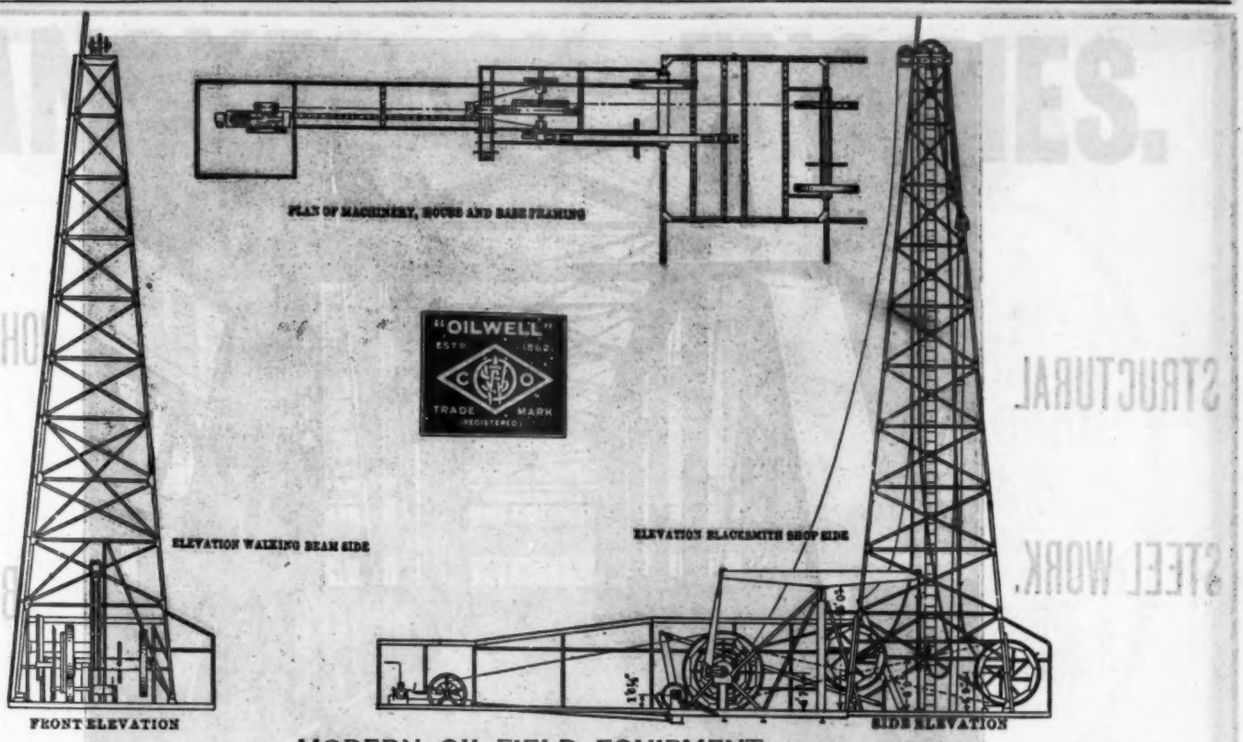

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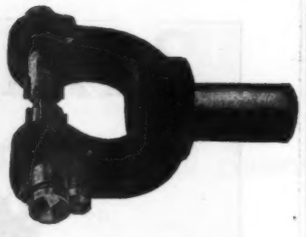

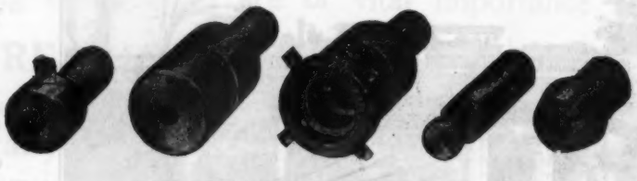

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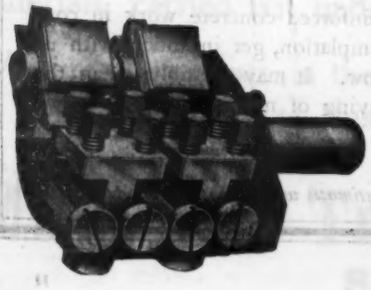

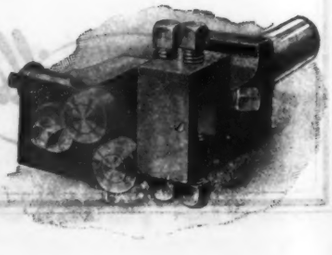

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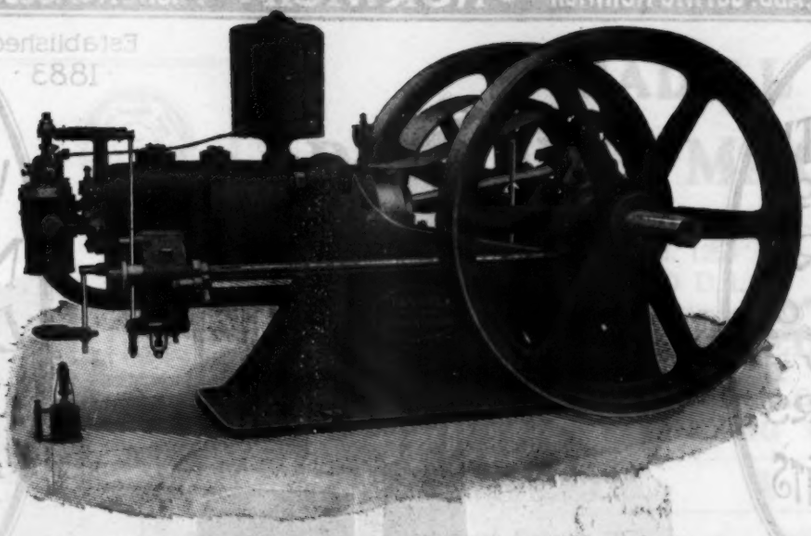

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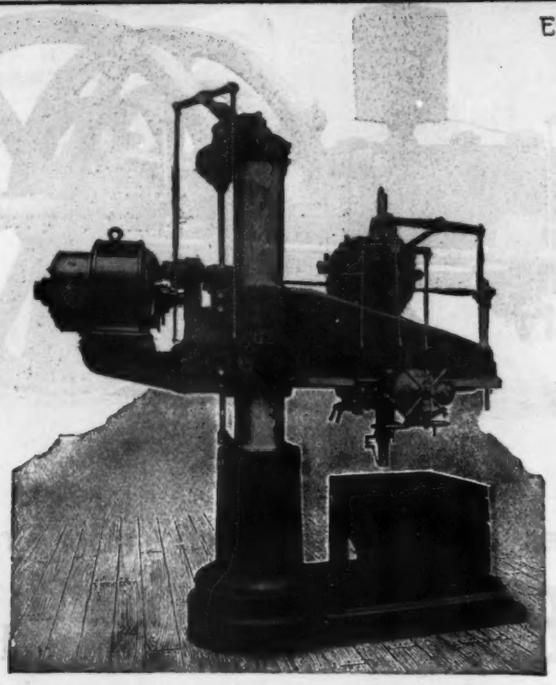

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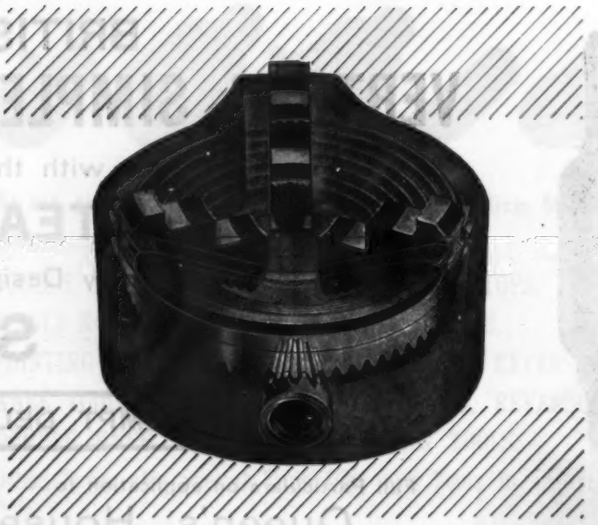

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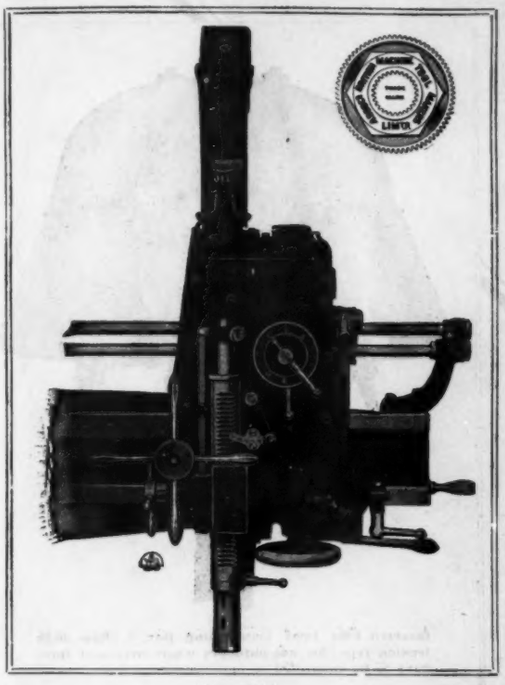

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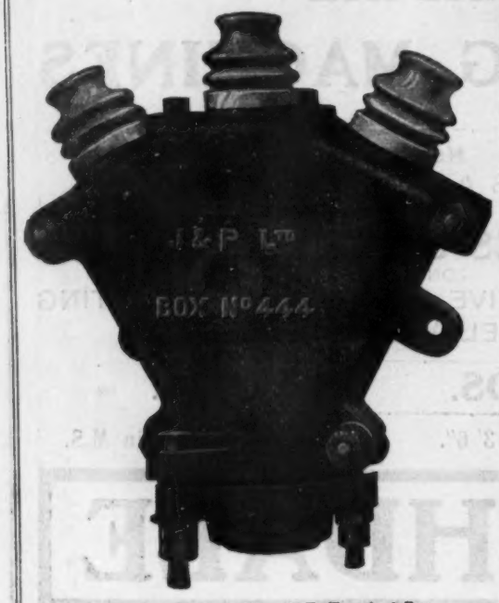

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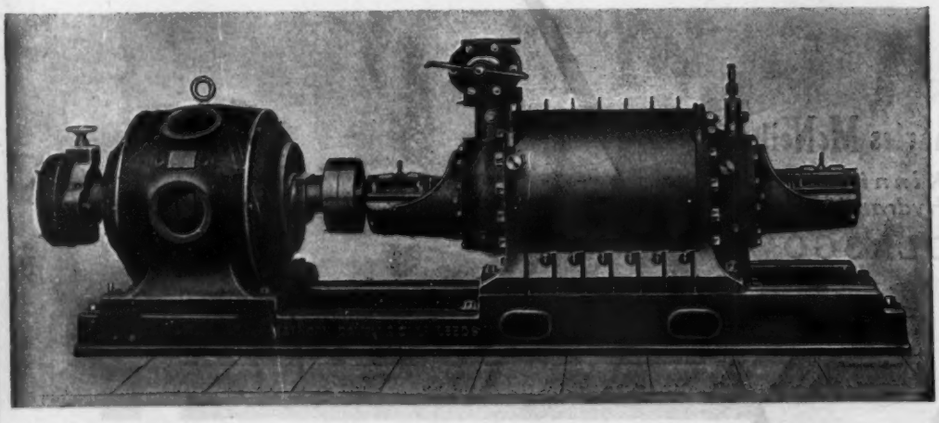

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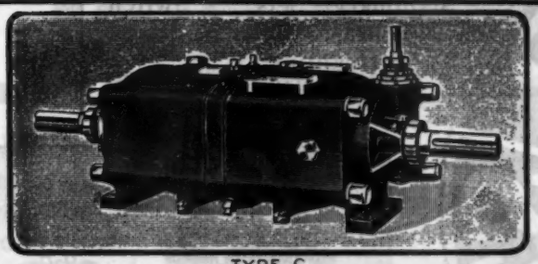

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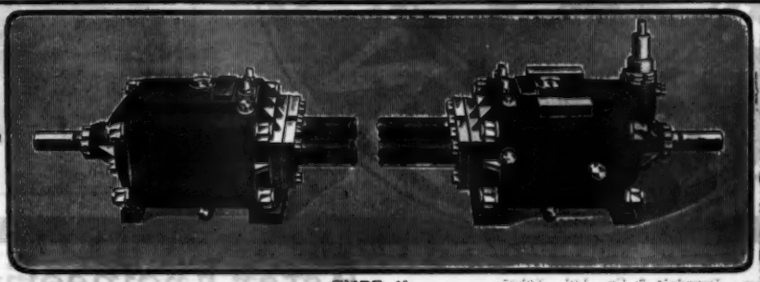

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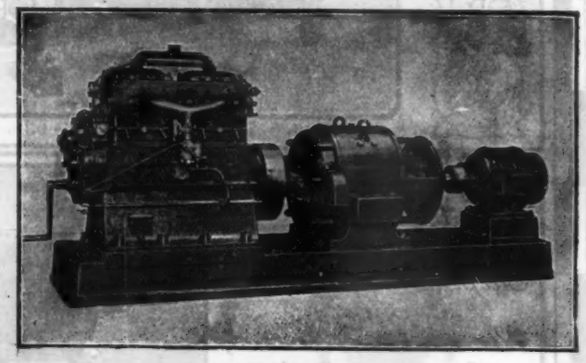

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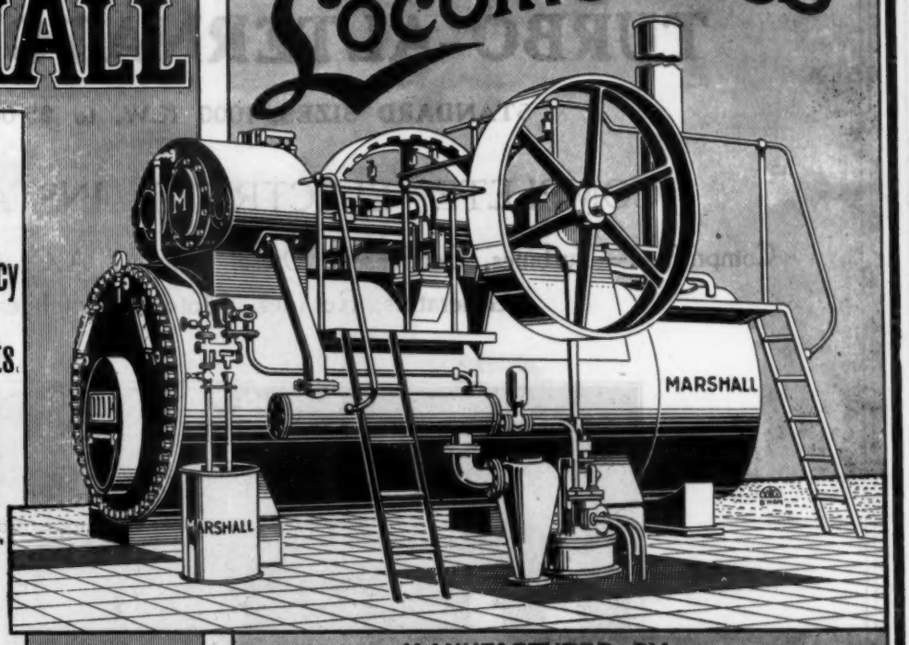

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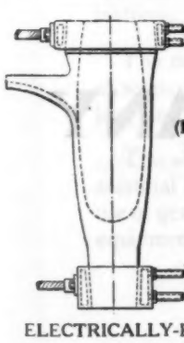

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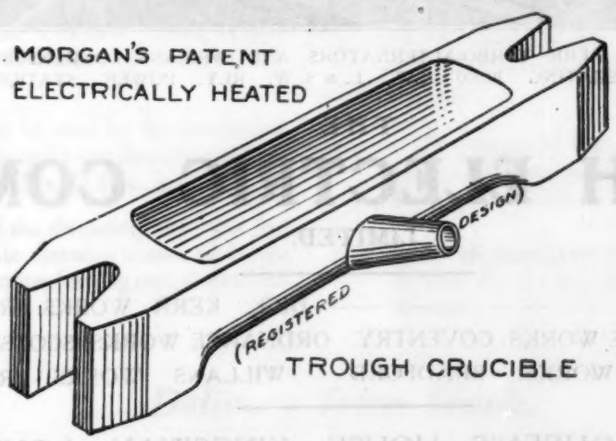

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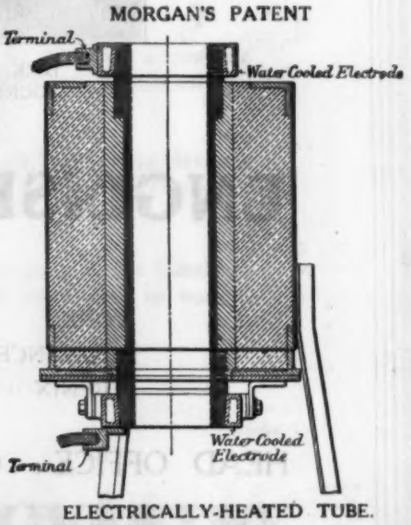

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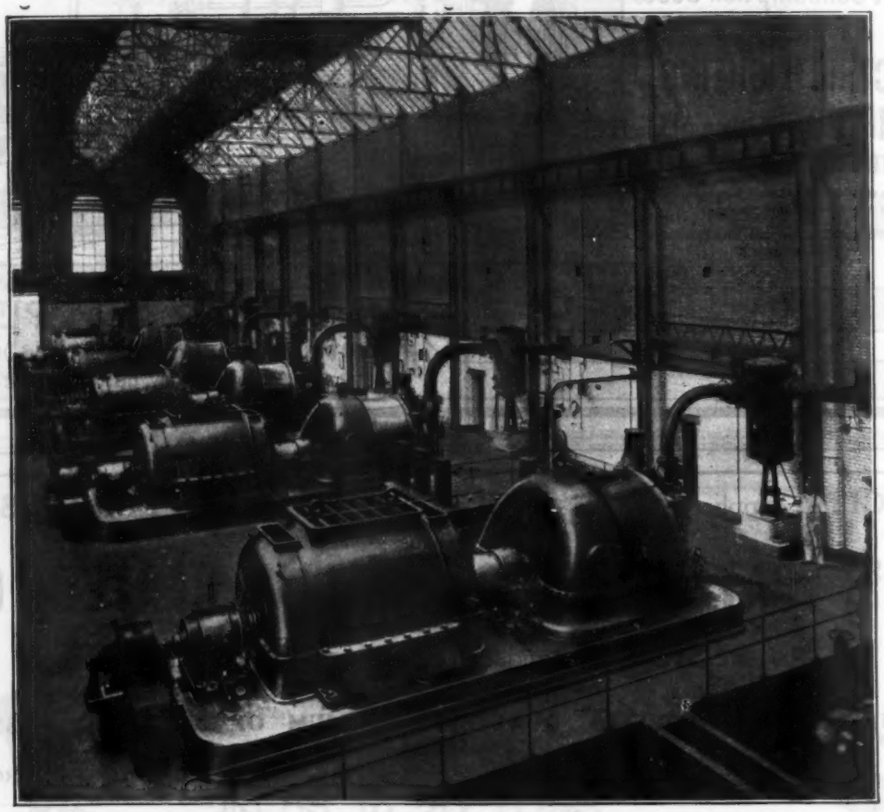

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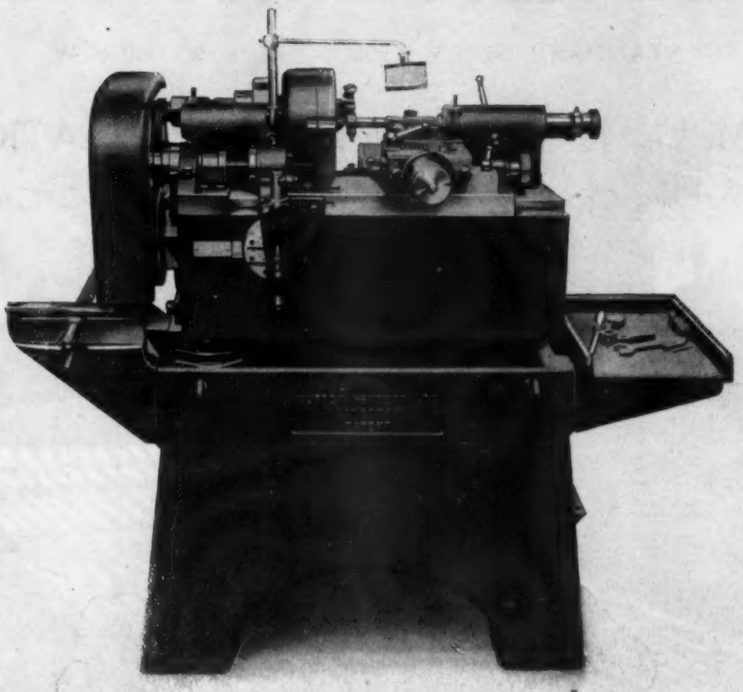

Precision Screw Cutting.

In the manufacture of the dies for use in our Coventry Self-Opening Dieheads it has been necessary to devise some means of producing hobs, whose teeth, in pitch and shape approach as near as possible to perfection.

The result of our efforts has been the development of the Precision Screw Lathe illustrated, which embodies a number of desirable features.

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The lead screw is positioned in the centre of the slide and ensures a straight pull on the saddle.

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The machine can be fixed on a concrete foundation eliminating all vibration from external sources.

The design of the pitch correcting device is such as will prevent any end pressure coming on the lead screw nut.

A full description is given in our Catalogue Section K, a copy of which will be sent on request.

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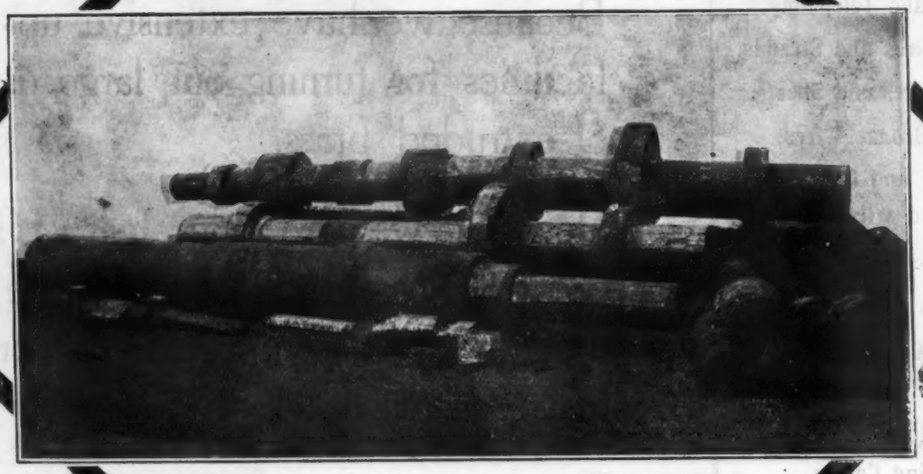

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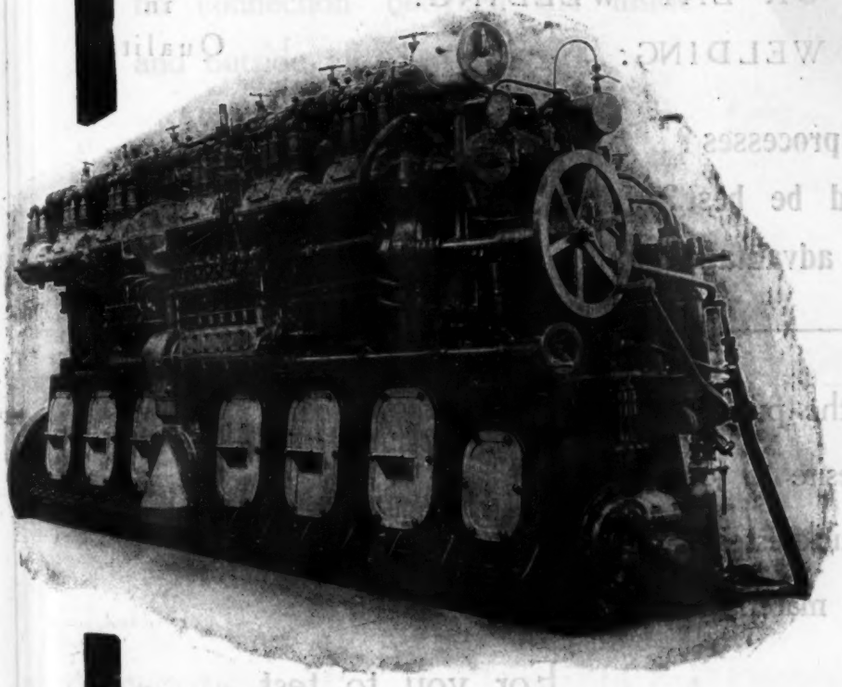

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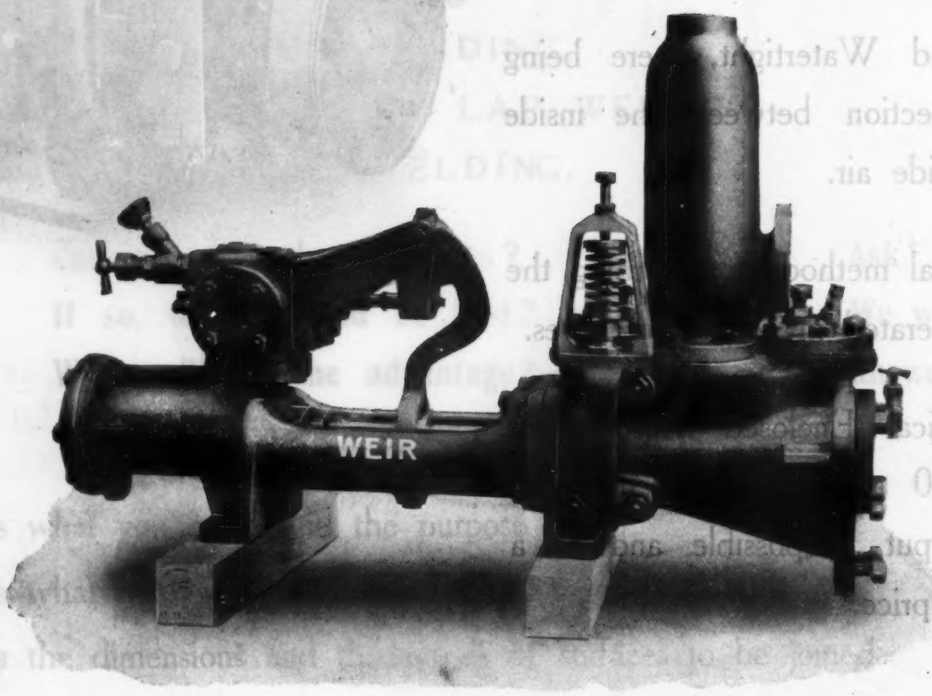

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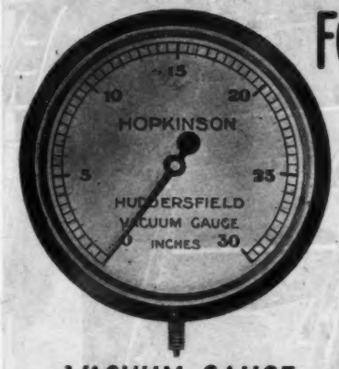
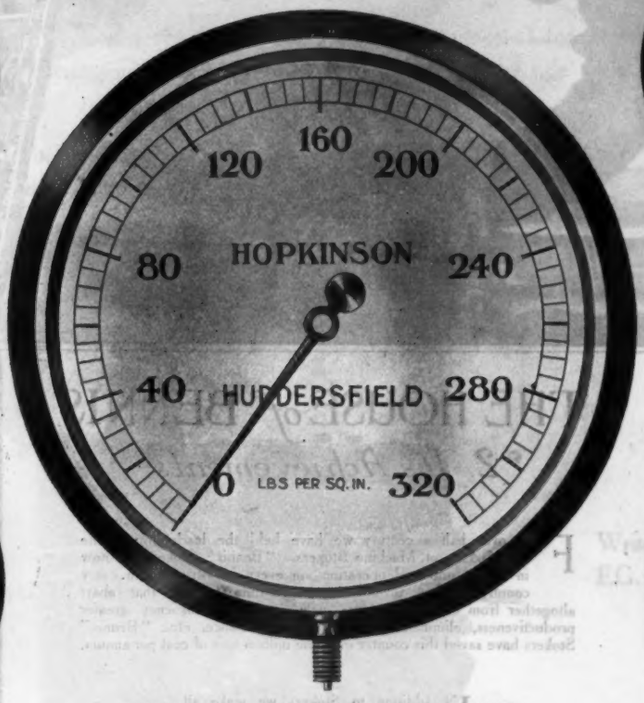
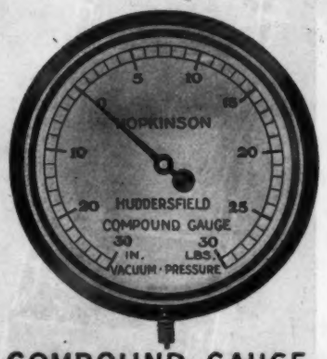


VACUUM GAUGE.
FIG. Nº 4060.



PRESSURE GAUGE.
FIG. Nº 4000.

TEST GAUGE
FIG. Nº 4100.



COMPOUND GAUGE.
FIG. Nº 4080.

HYDRAULIC GAUGE.
FIG. Nº 4120.

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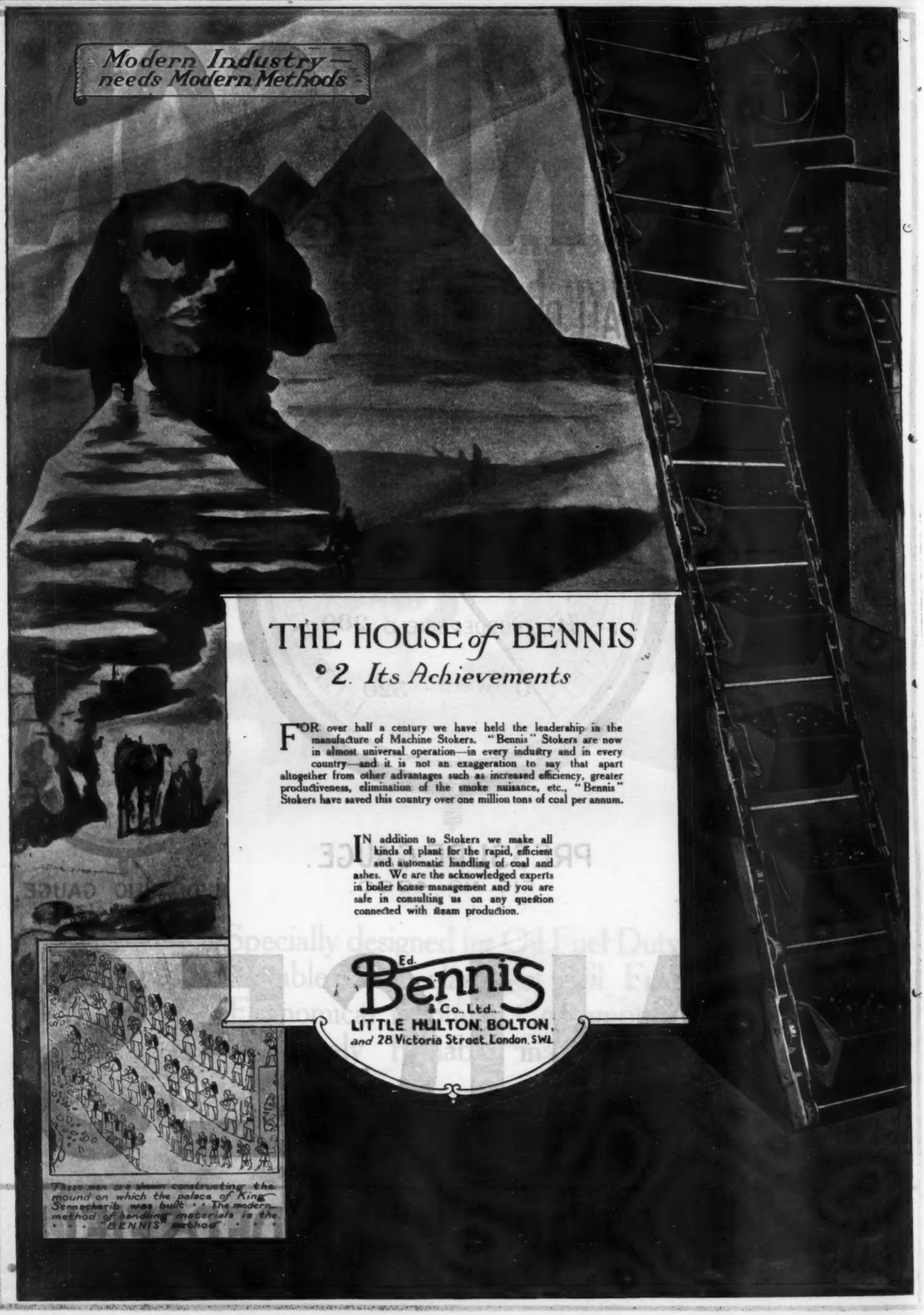

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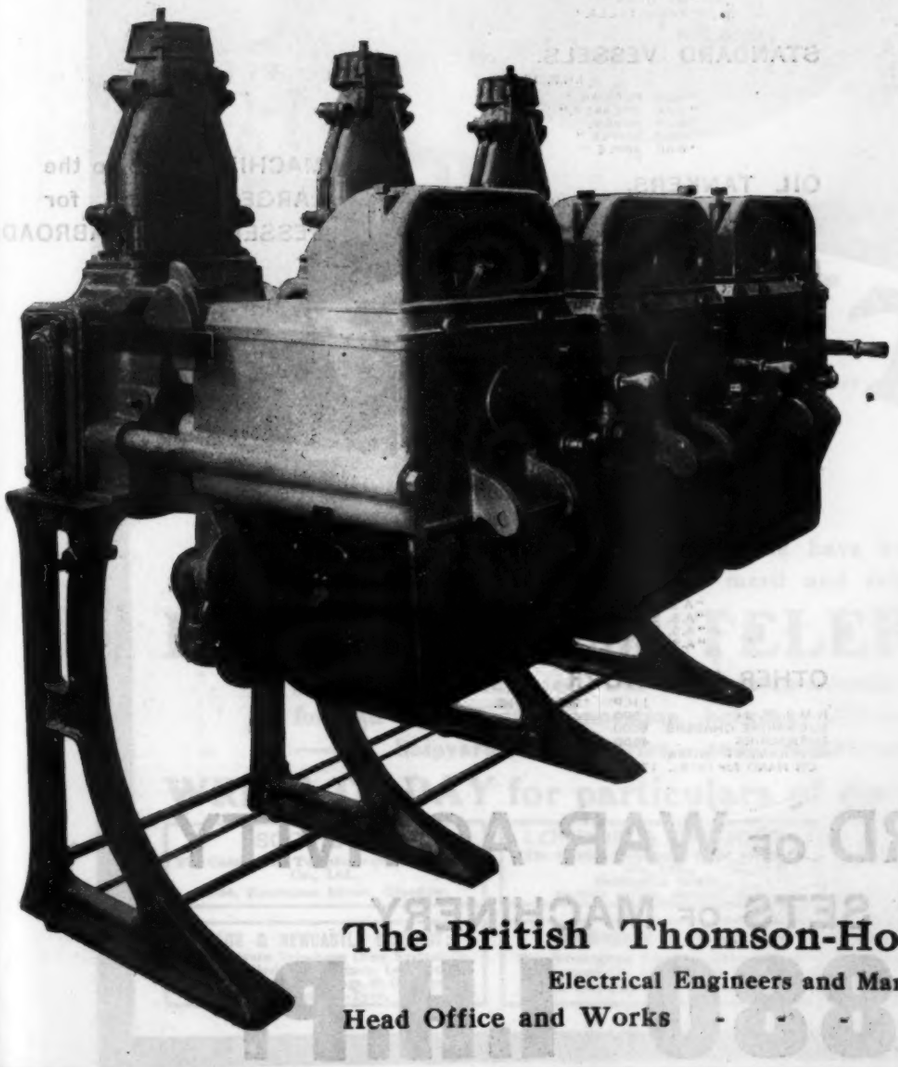

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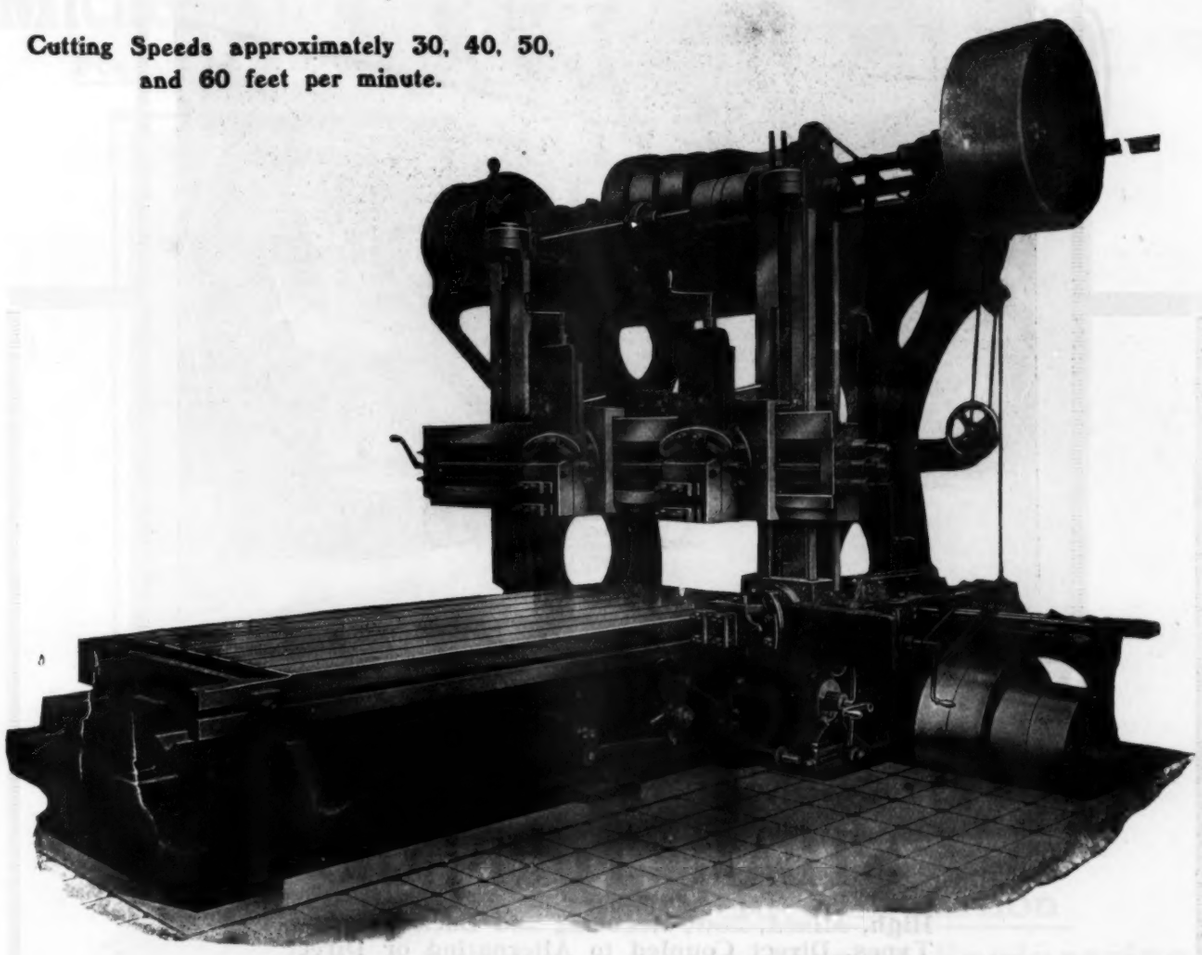

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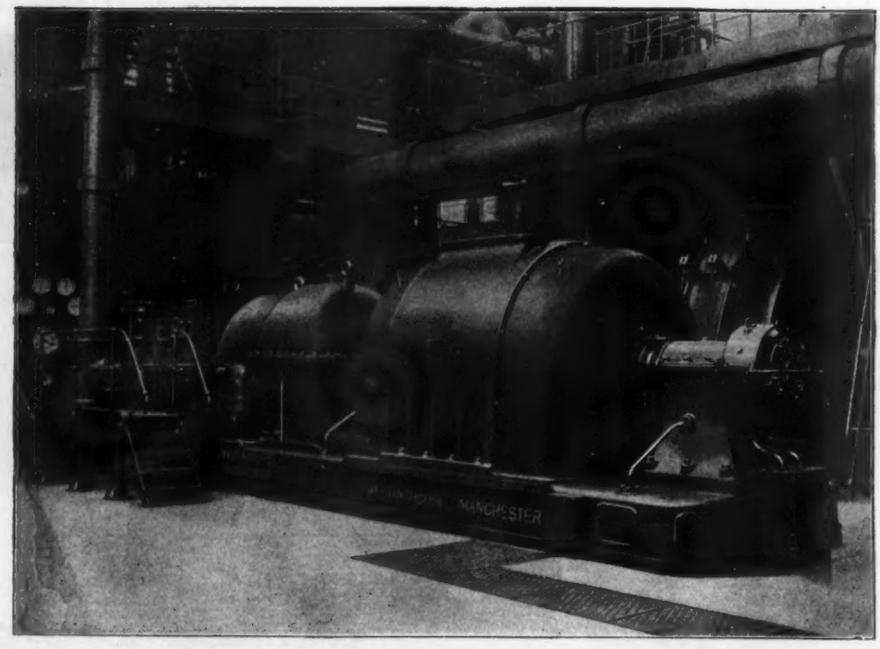

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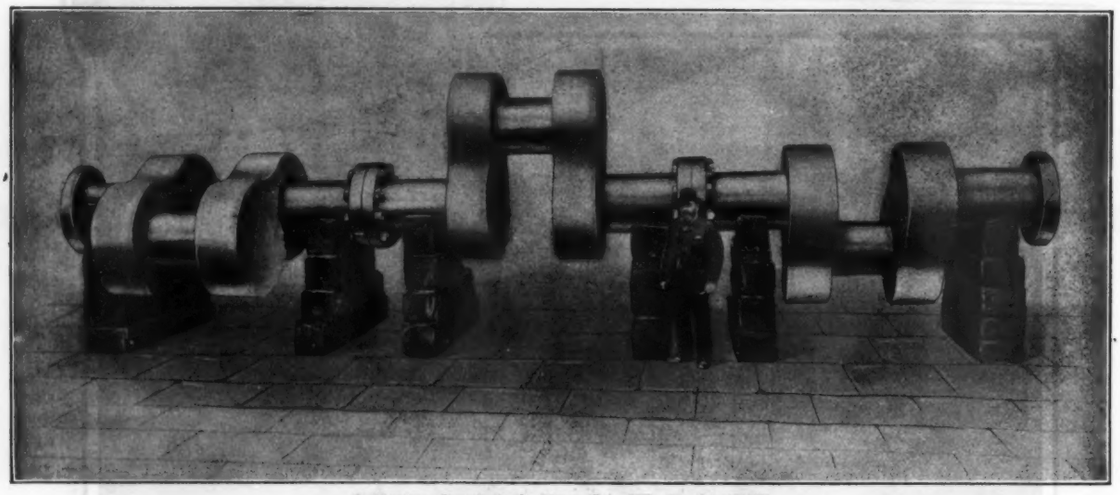

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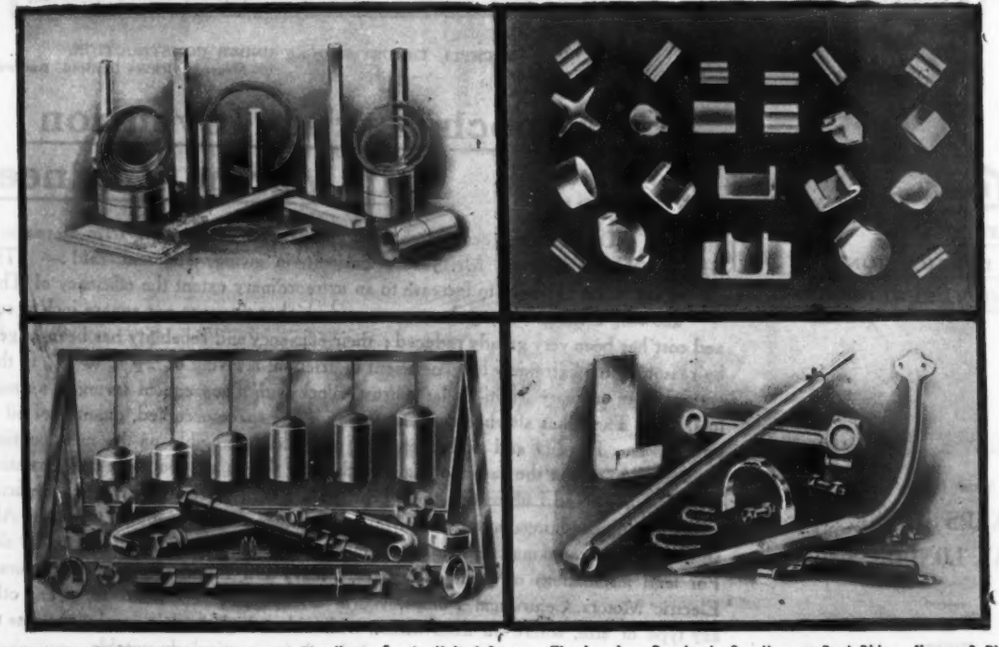

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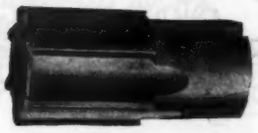

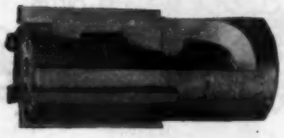

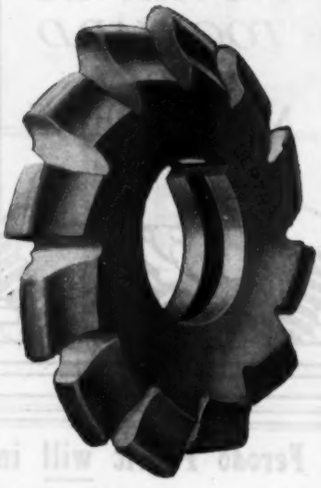

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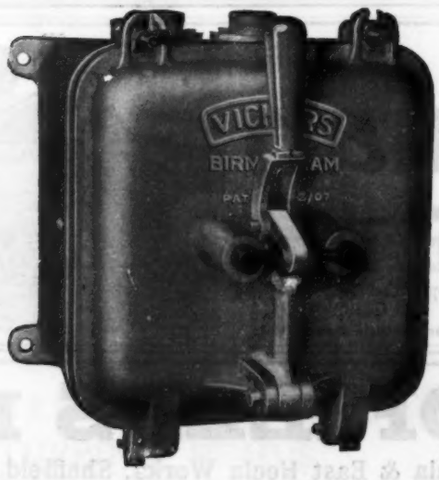

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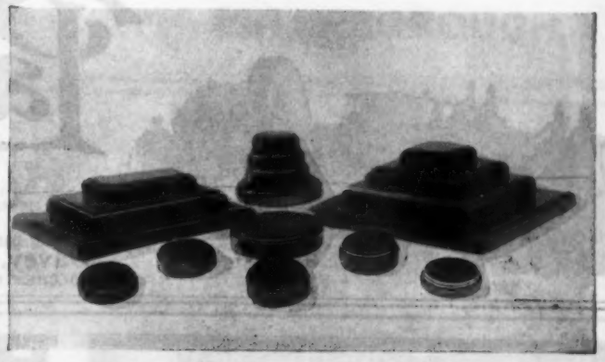

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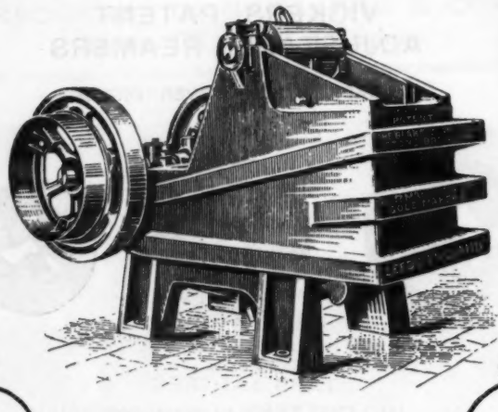

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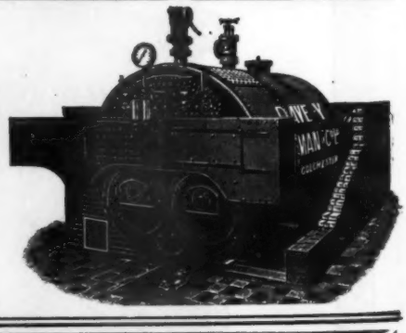

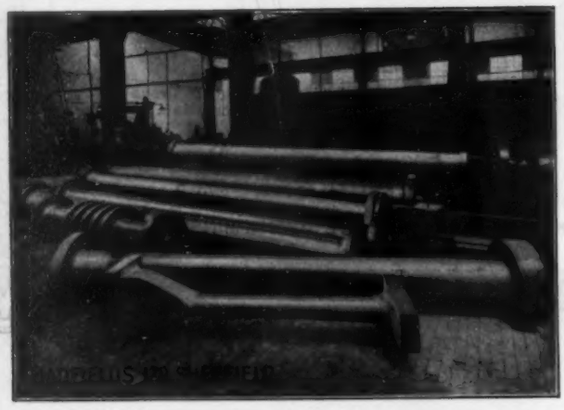

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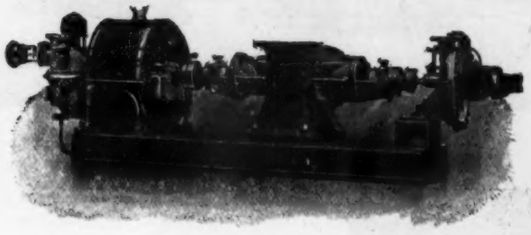

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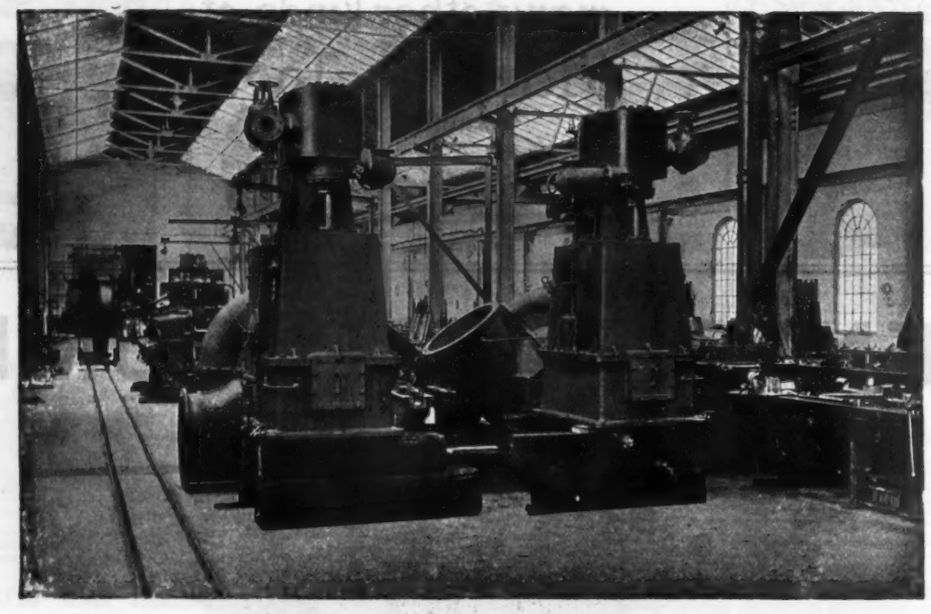
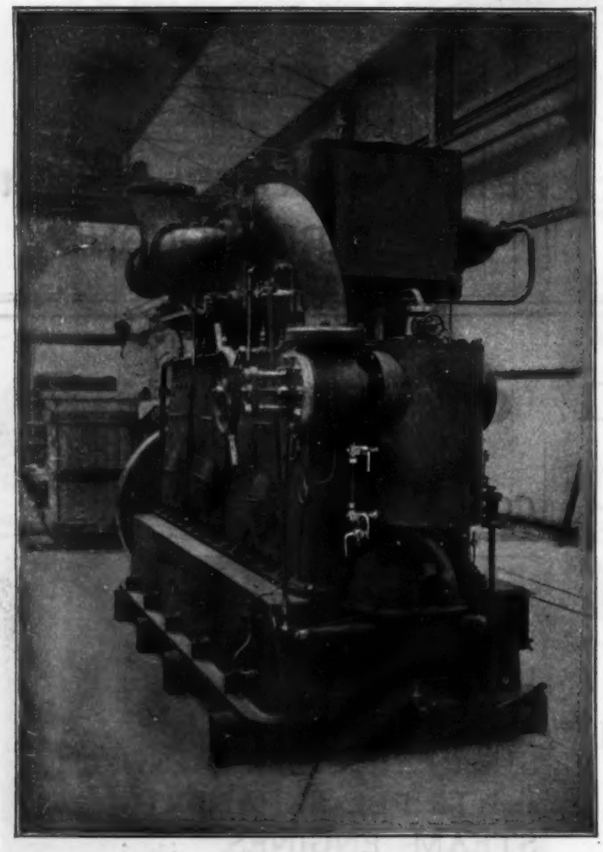
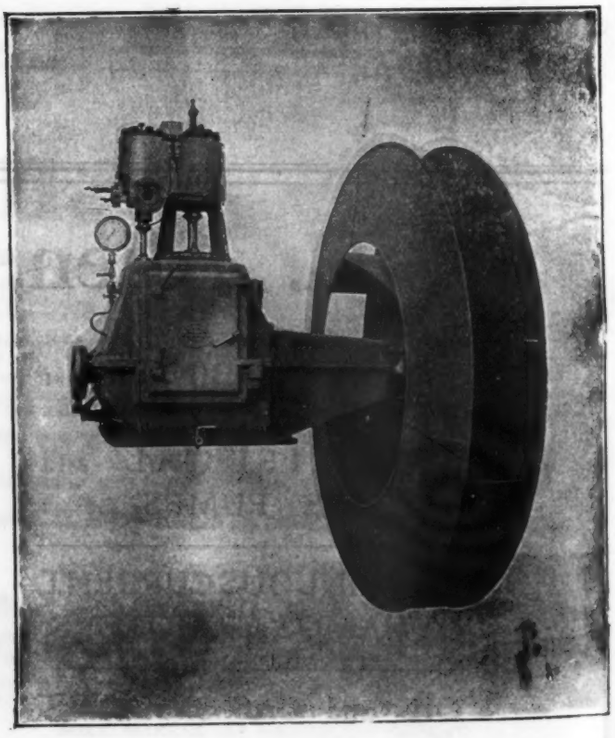




DYNAMO ENGINES.



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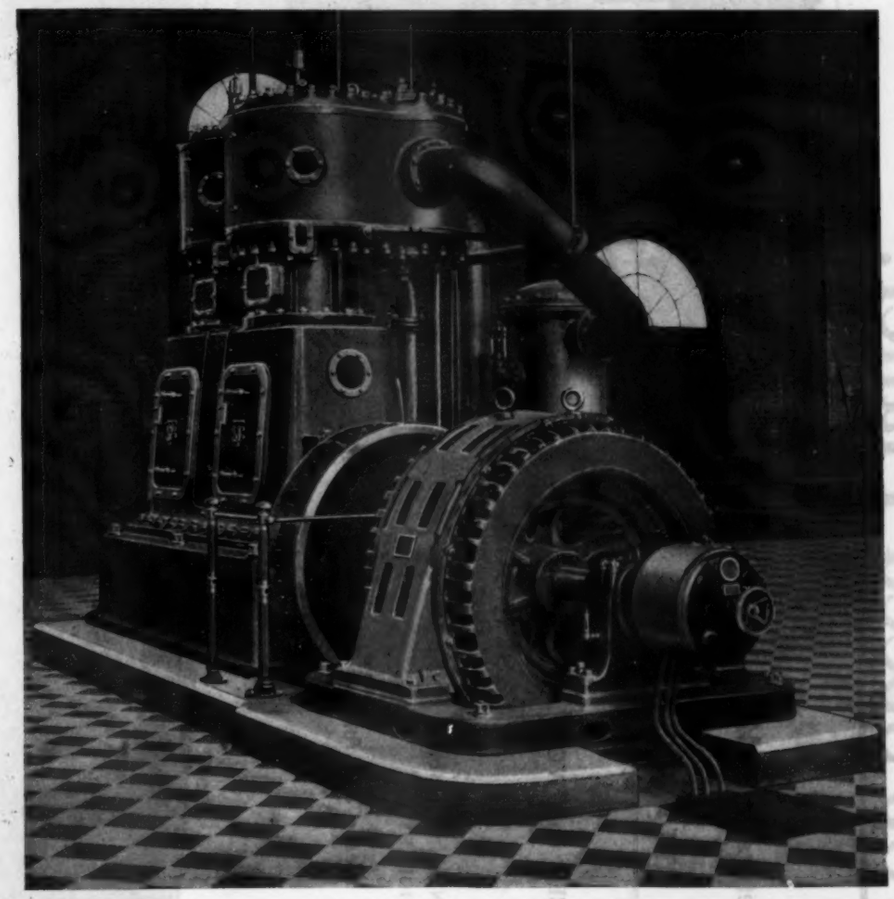

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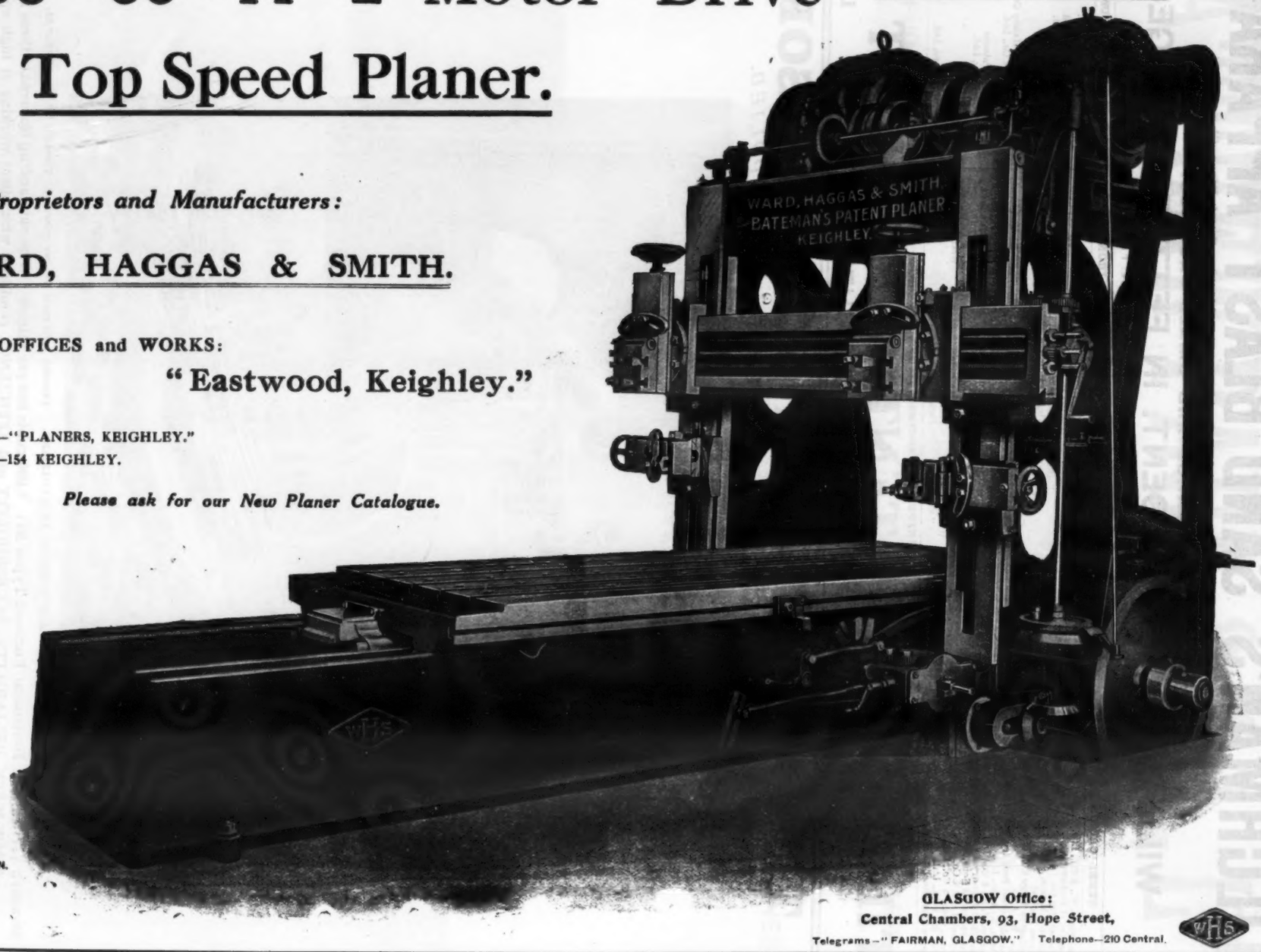

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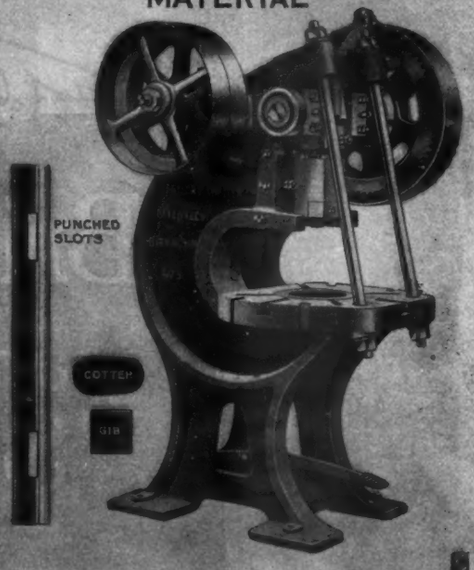

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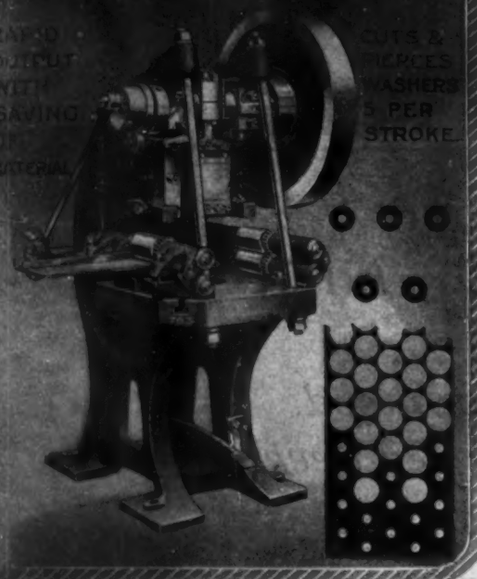

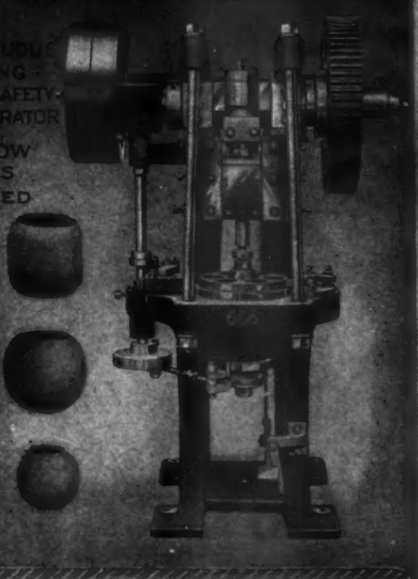

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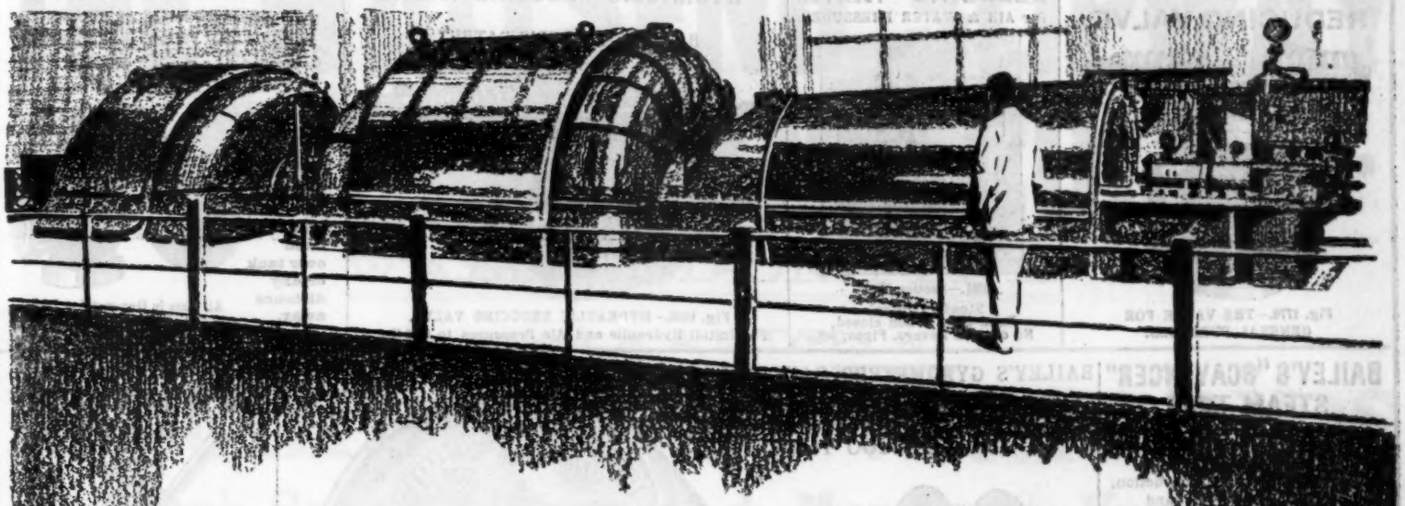

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Fig. 1778.—THE VALVE FOR GENERAL PURPOSES.

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For AIR & WATER PRESSURES.

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CLASS "Z"
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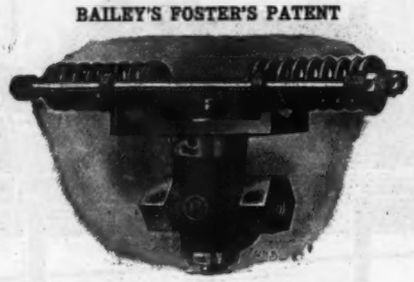

Fig. 1929.—HYDRAULIC REDUCING VALVE.
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Fig. 5149.—"B.B." Type GYROMETER.

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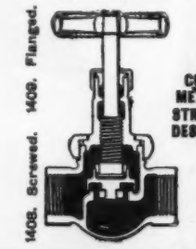

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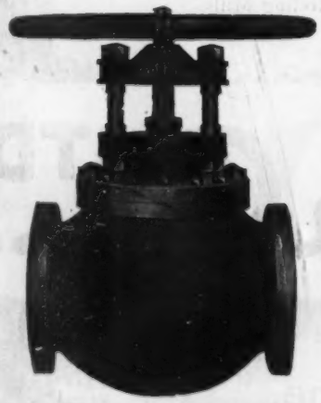

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Fig. 1428—Iron. Fig. 1897—Steel.

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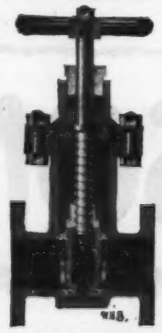

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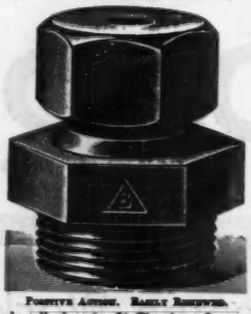

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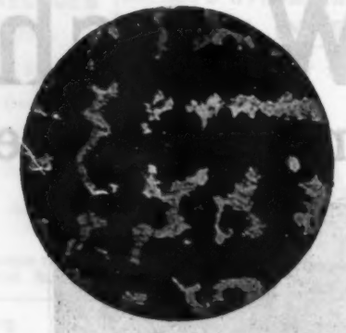

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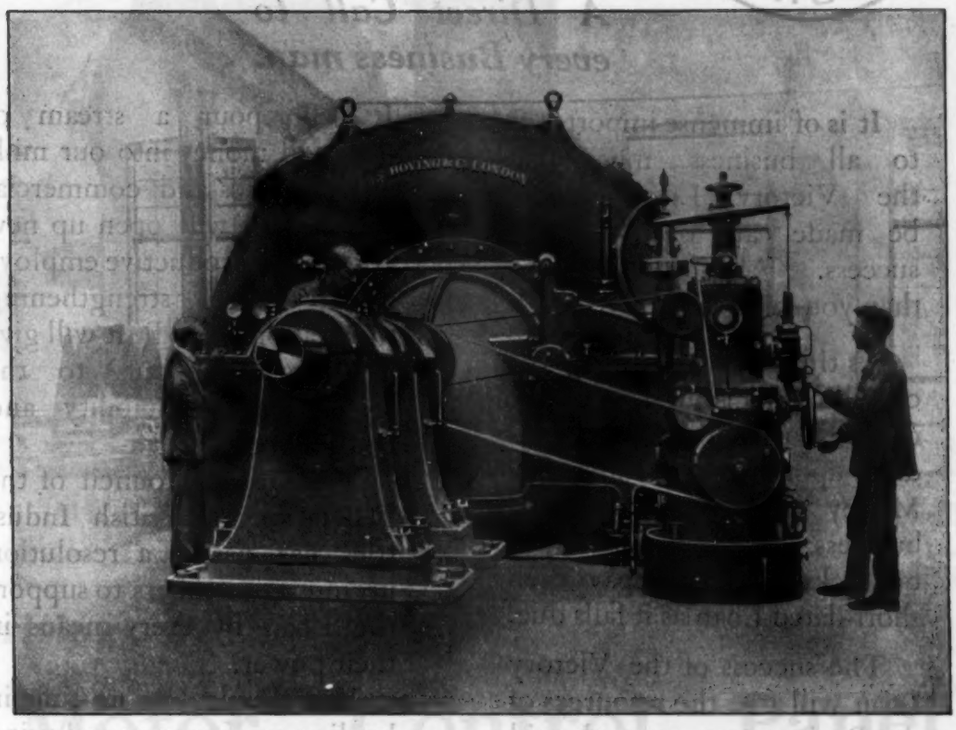

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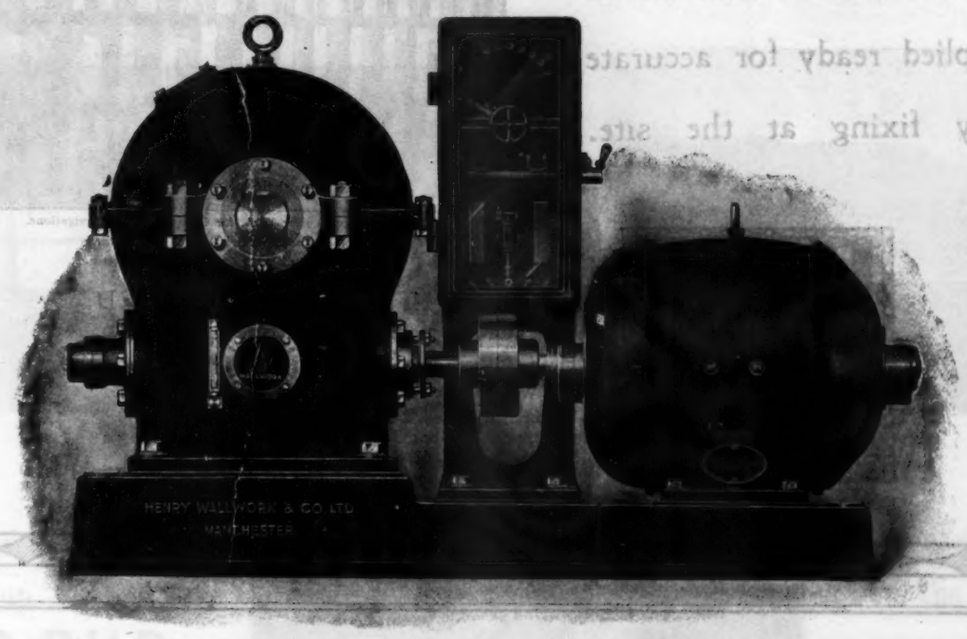

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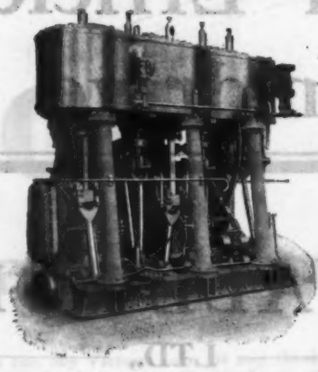

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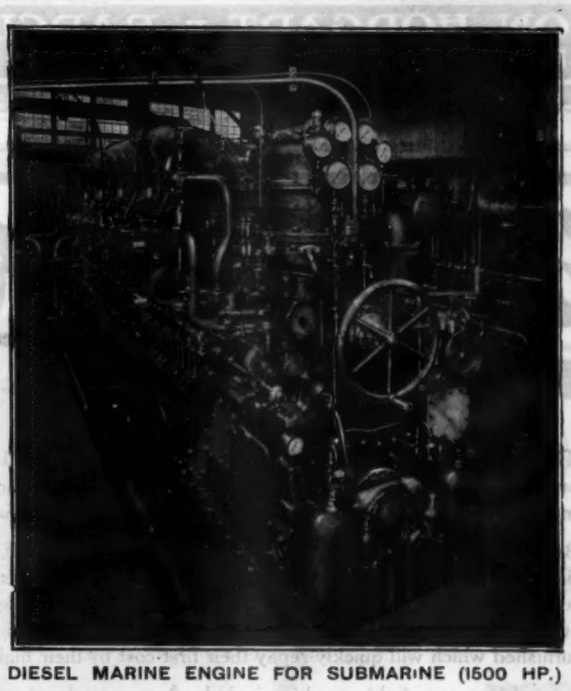

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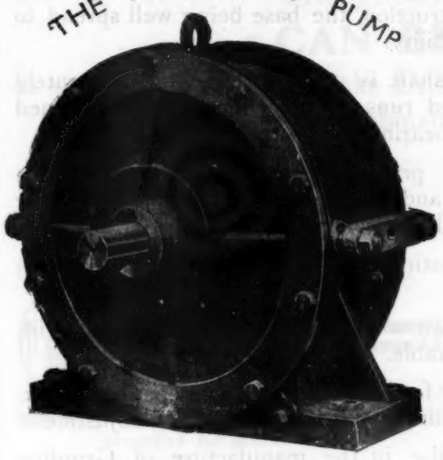

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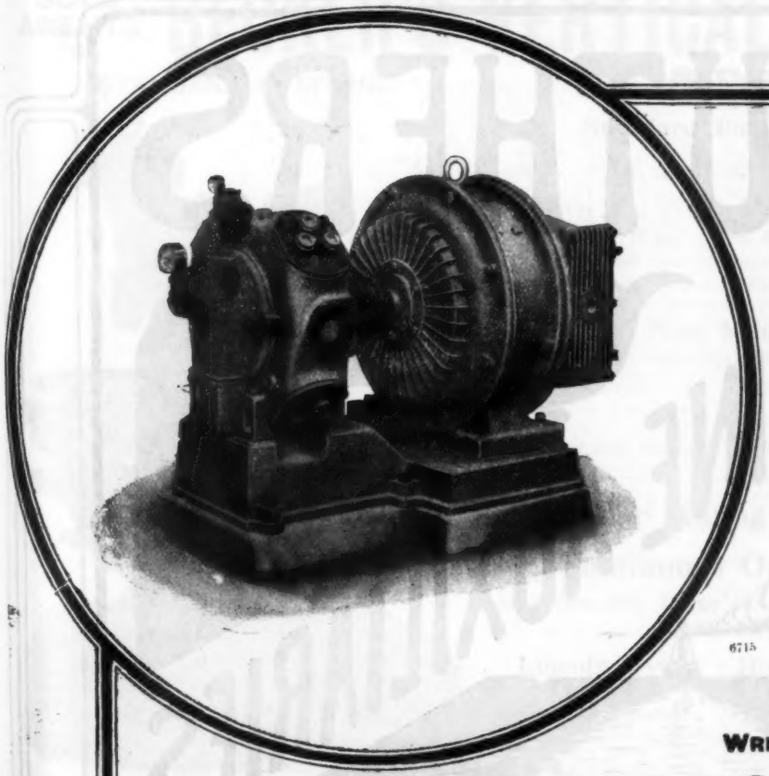

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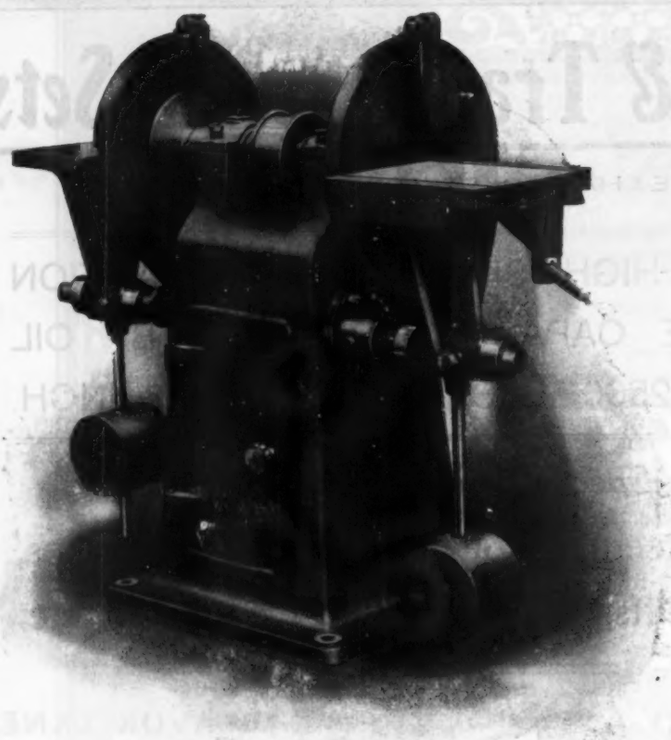

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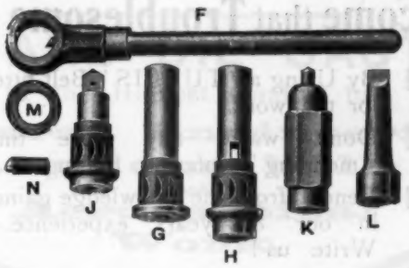

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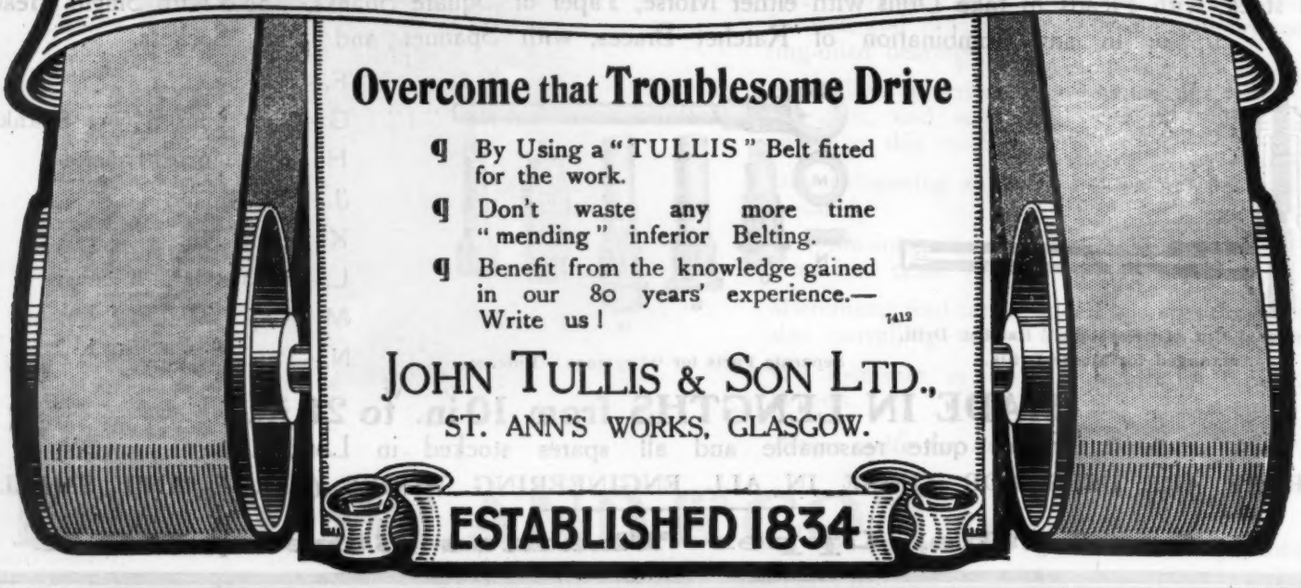

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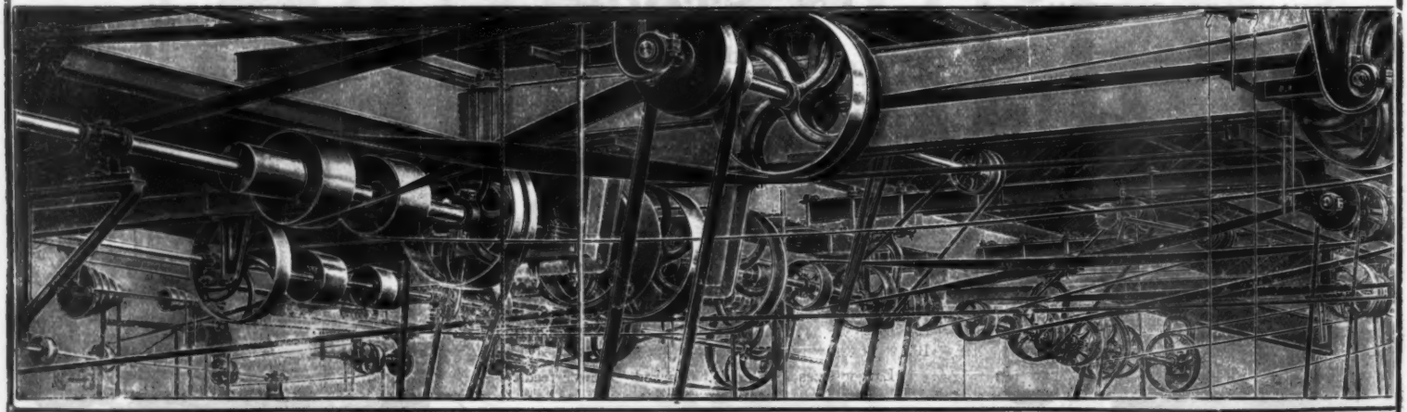

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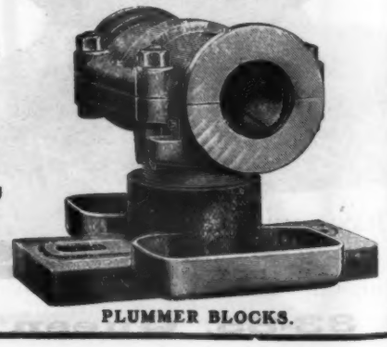

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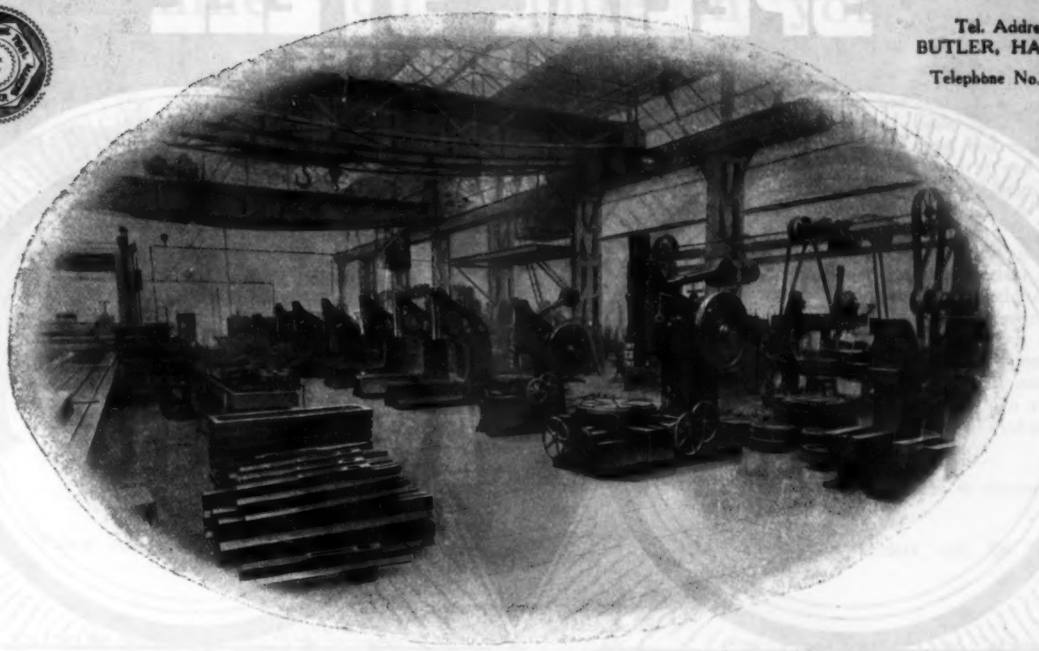

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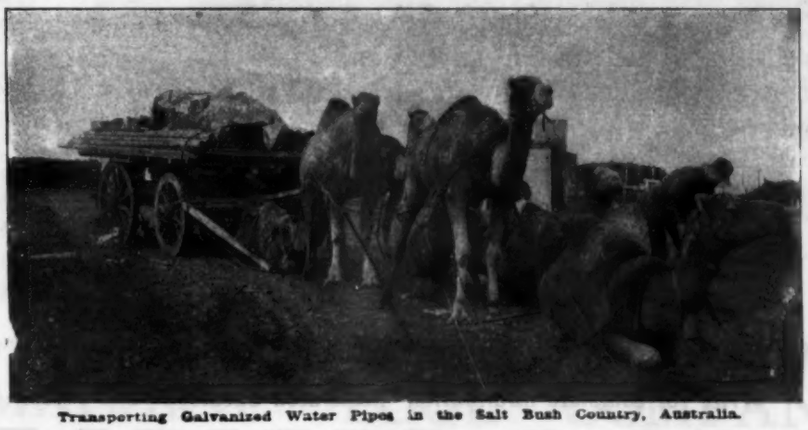

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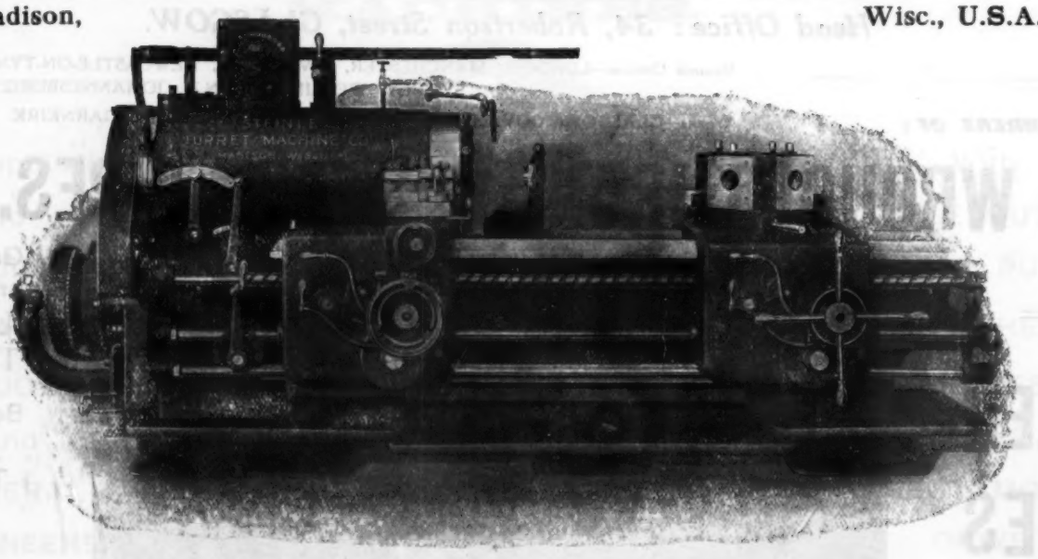

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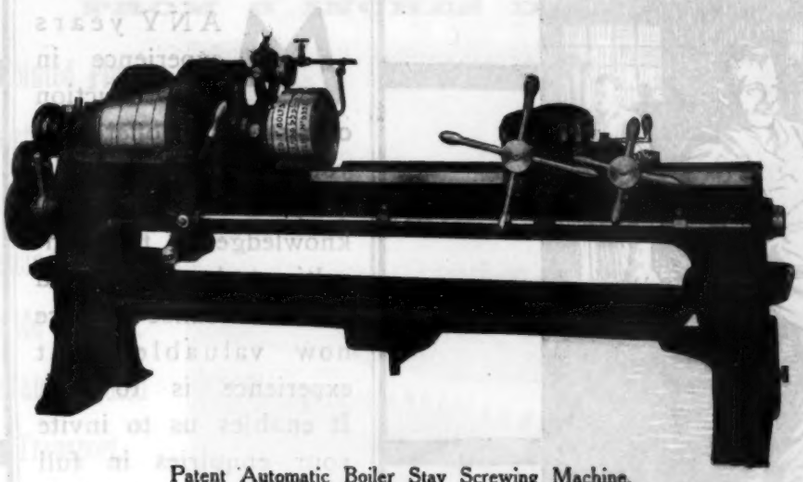

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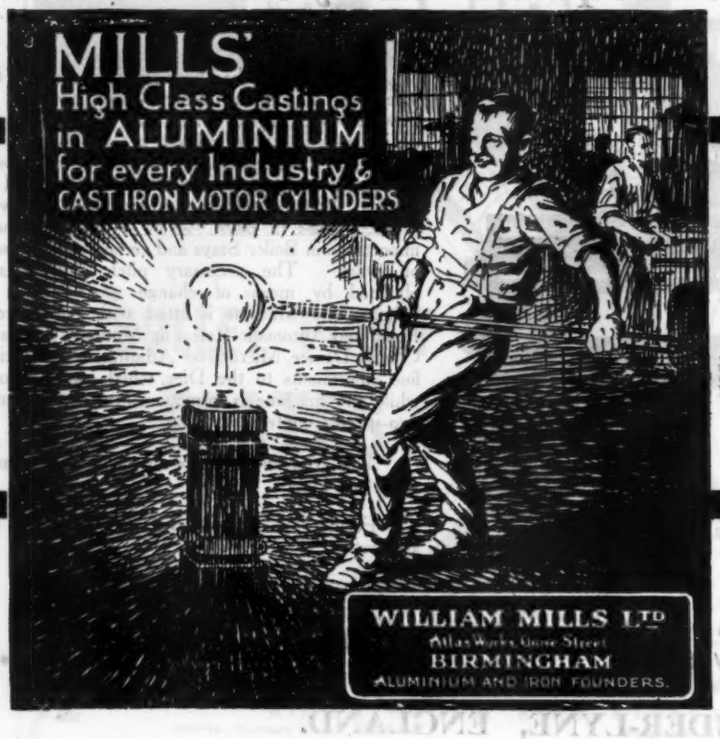

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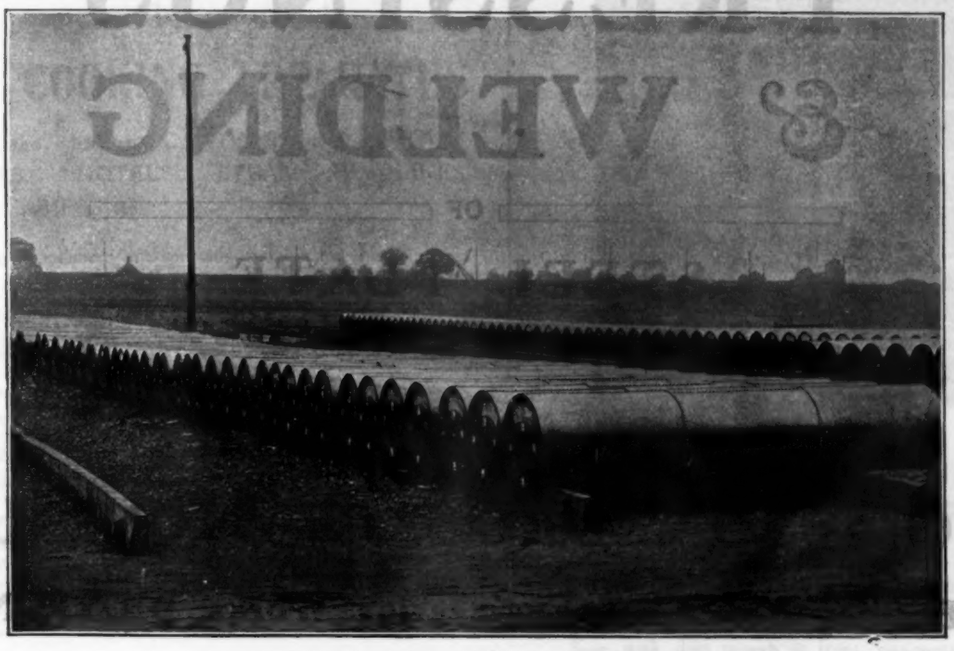

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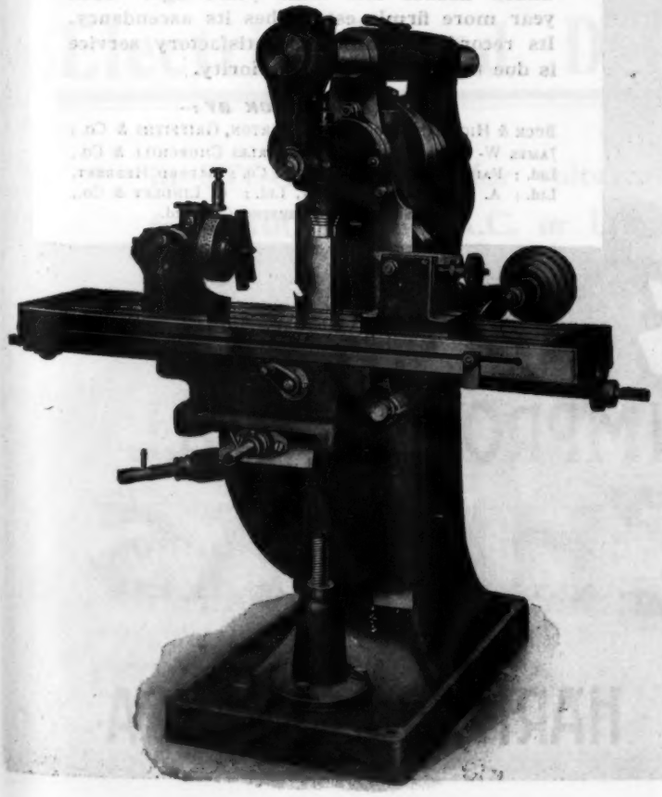

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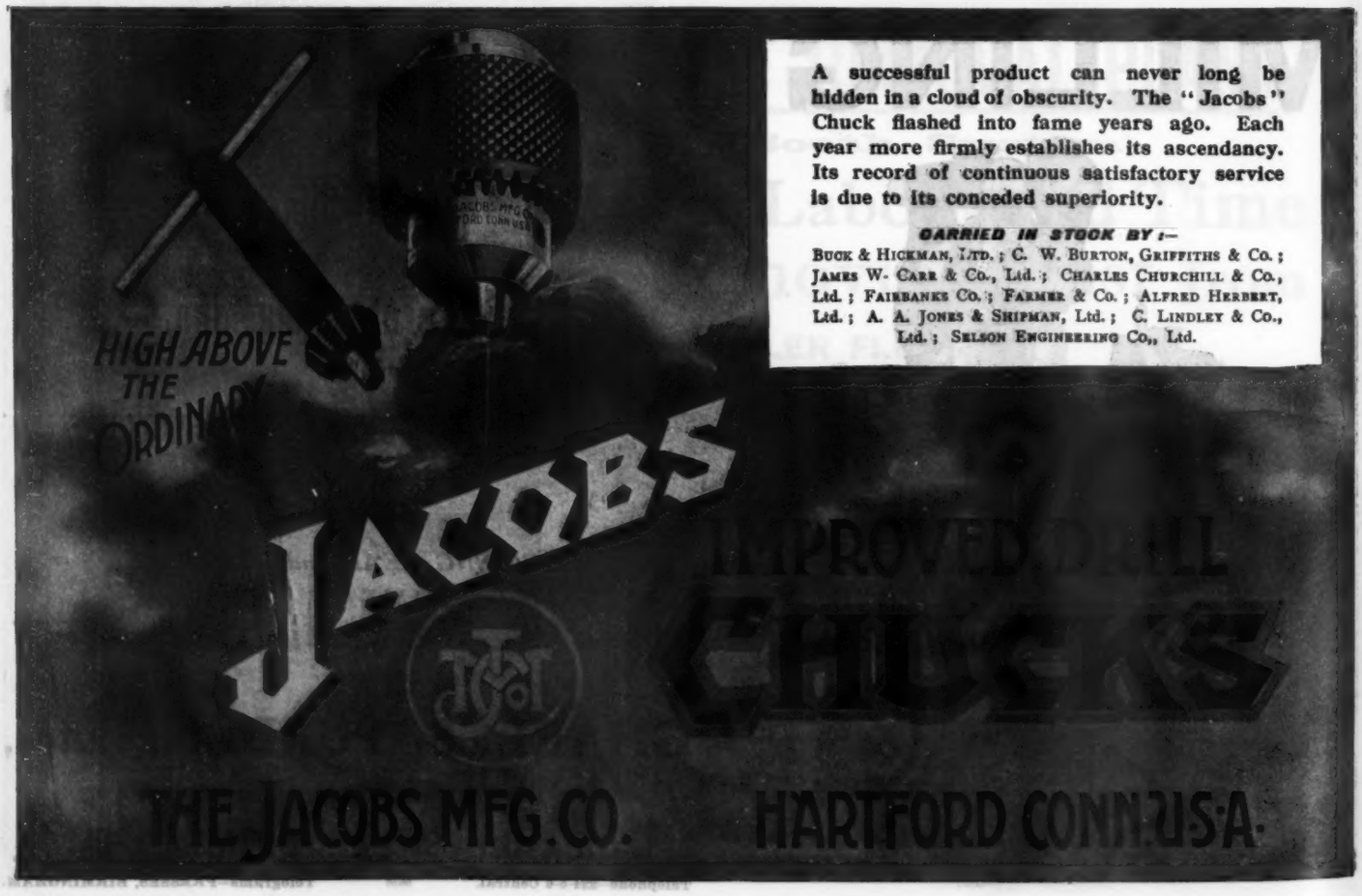

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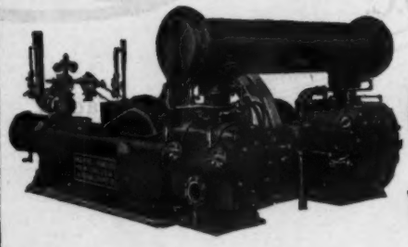

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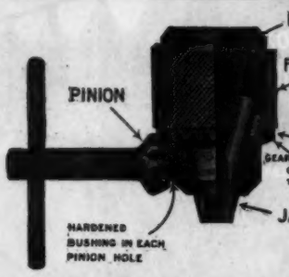

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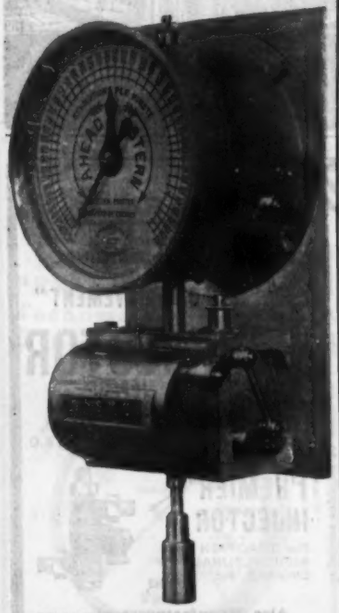

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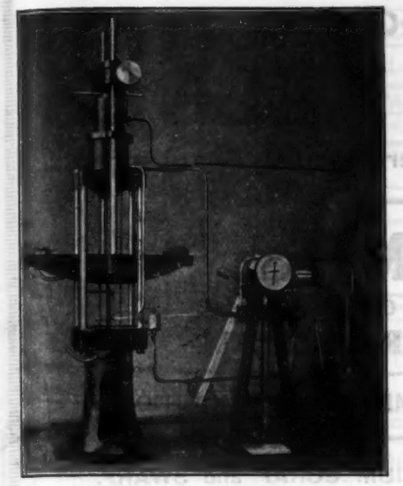

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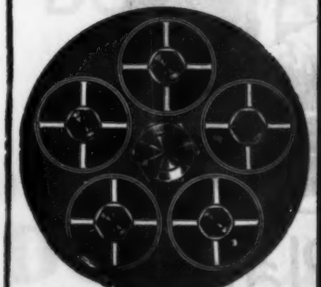

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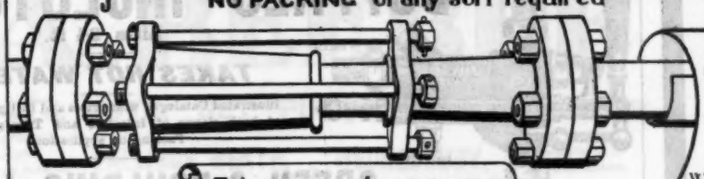

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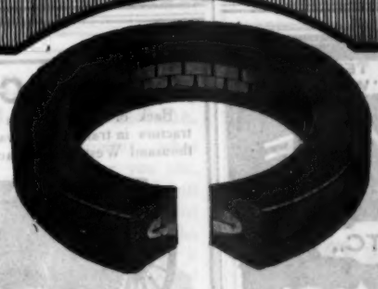

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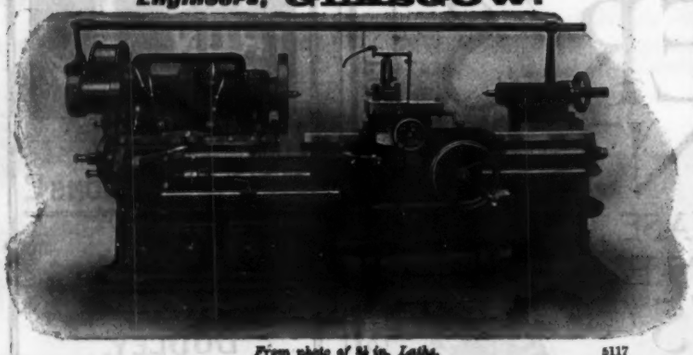

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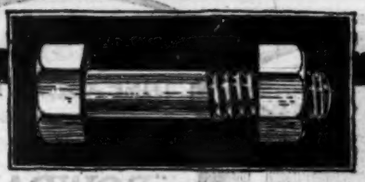

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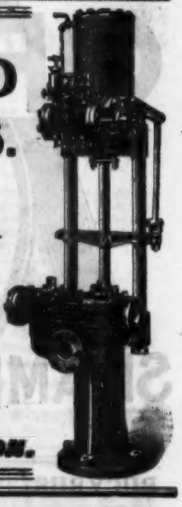

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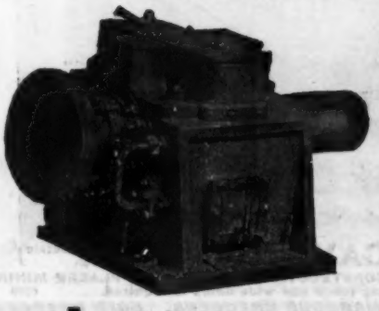

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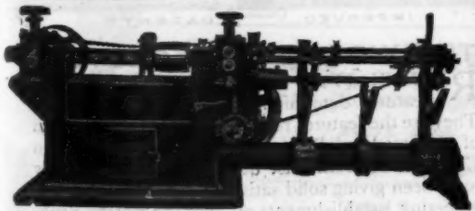

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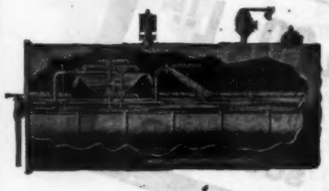

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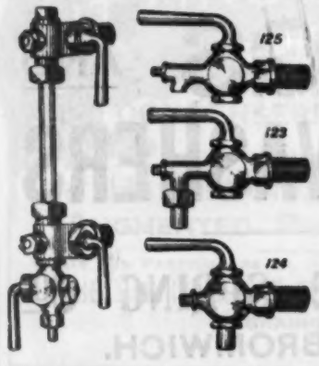

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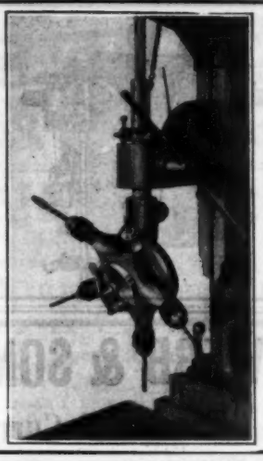

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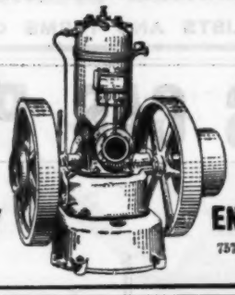

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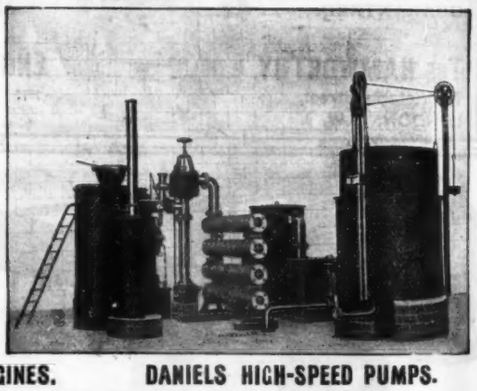

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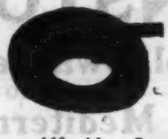
No. 3.  No. 4. WITH DOUBLE PIN.

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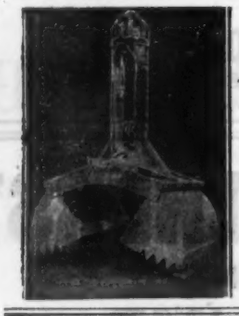

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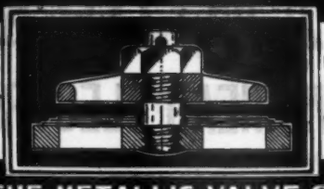

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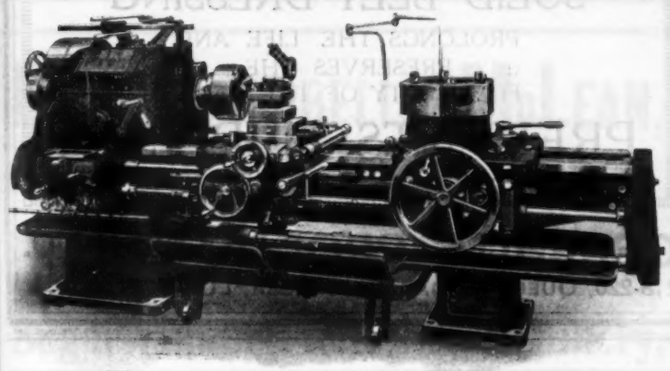

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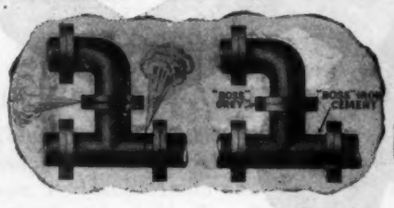

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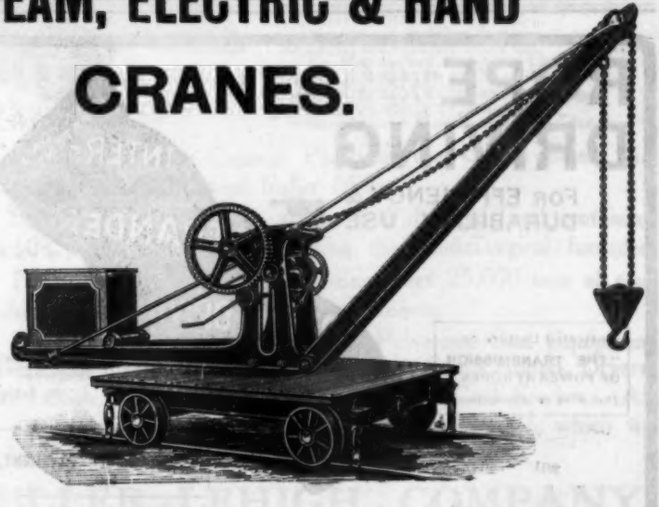

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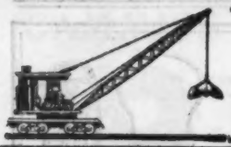

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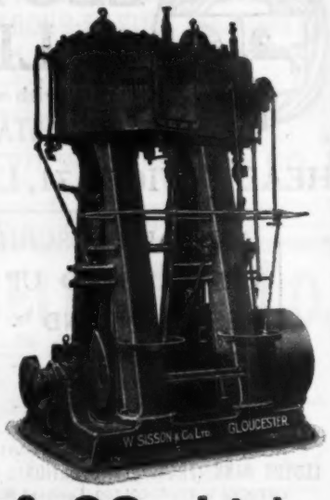

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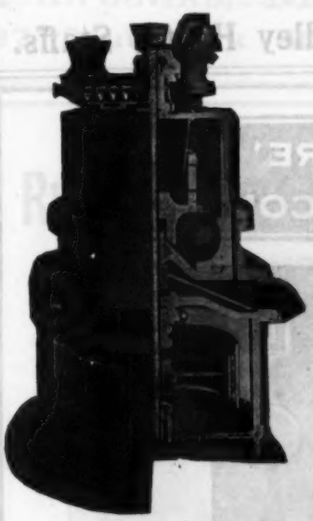

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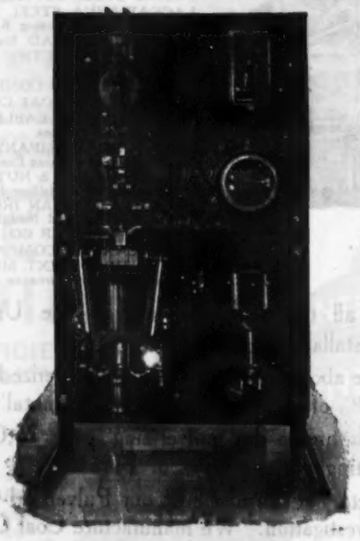

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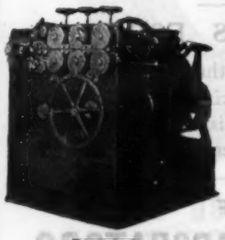

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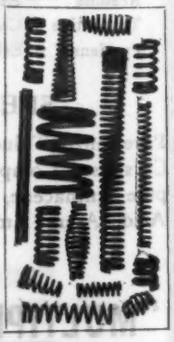

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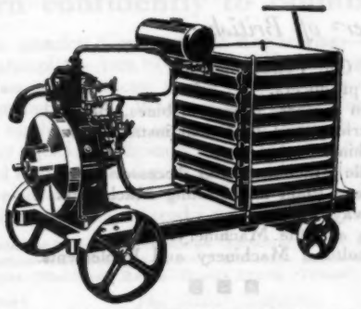

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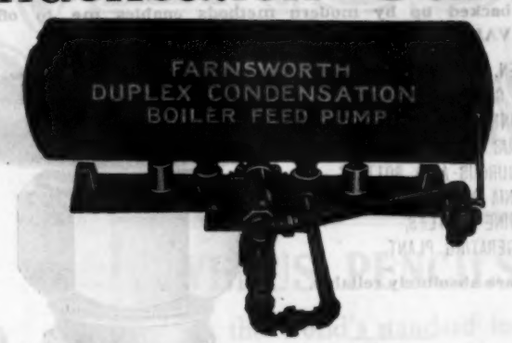

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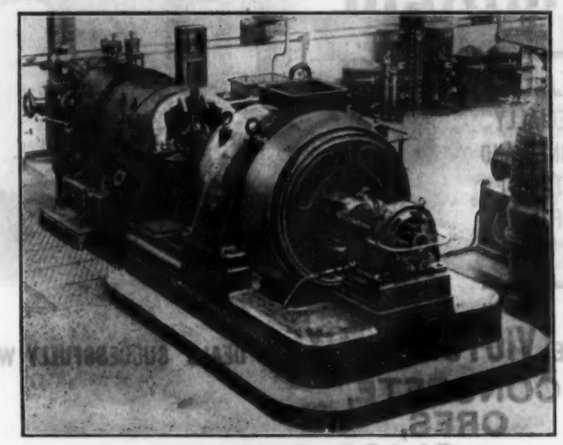

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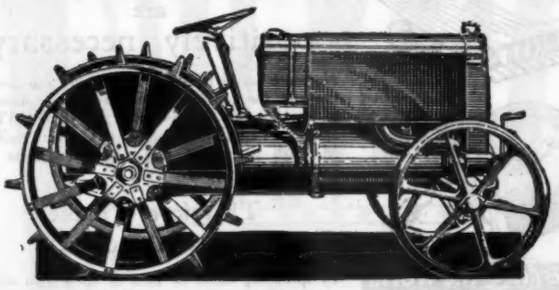

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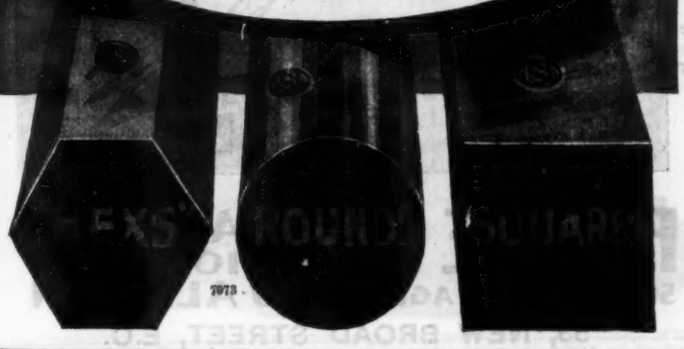

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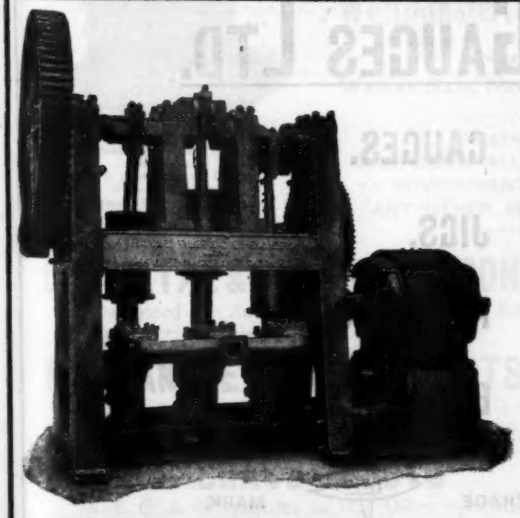

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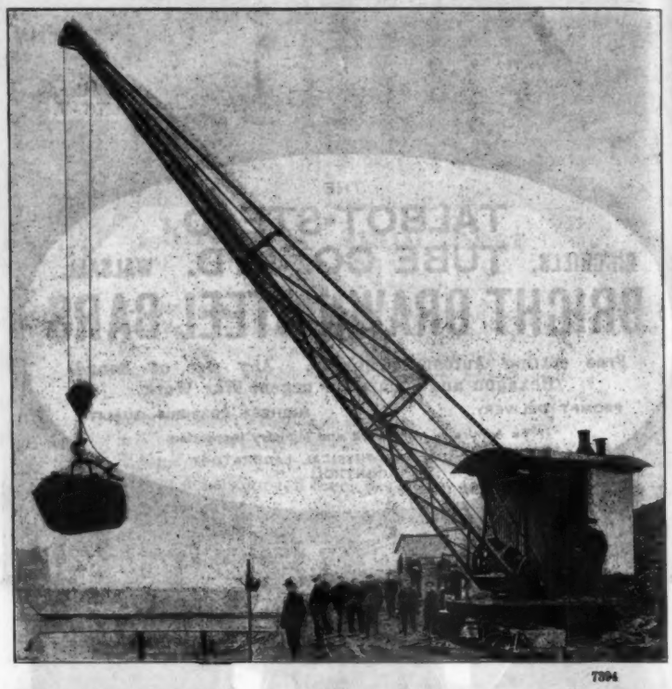

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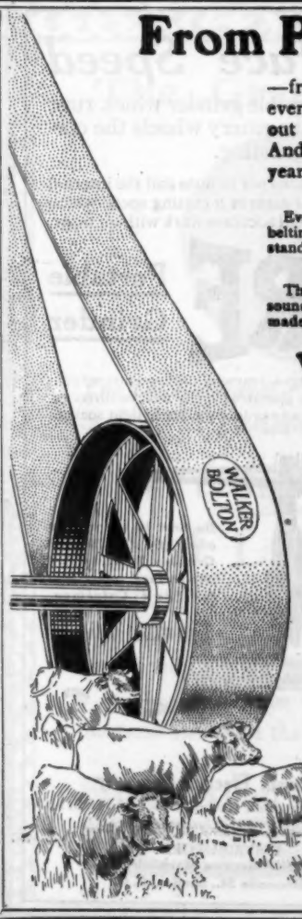

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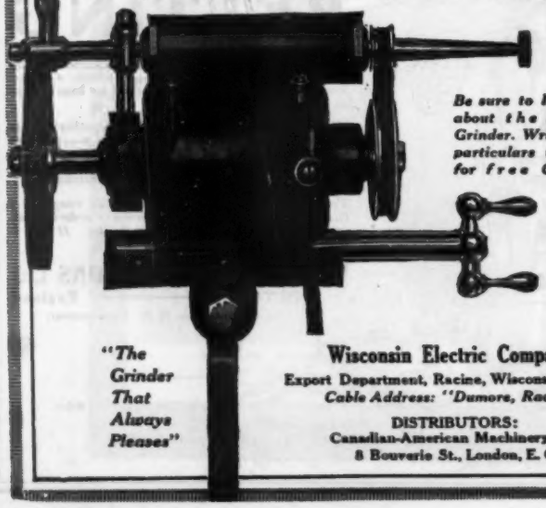

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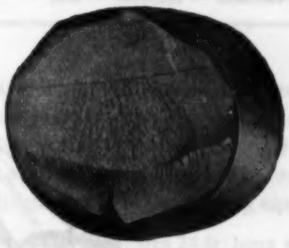

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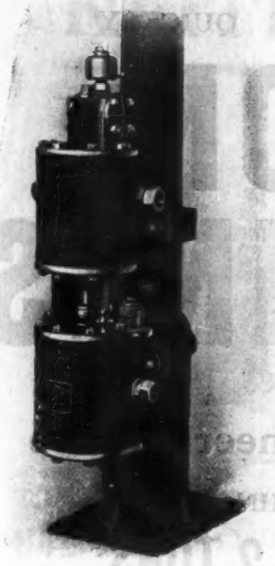

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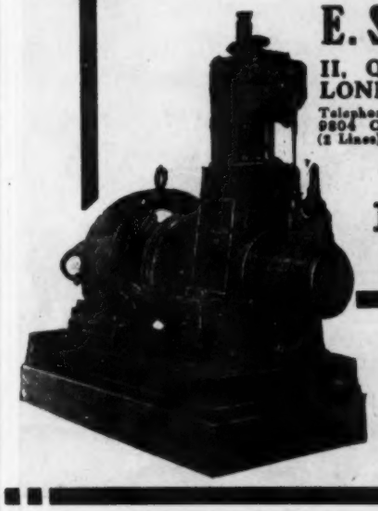

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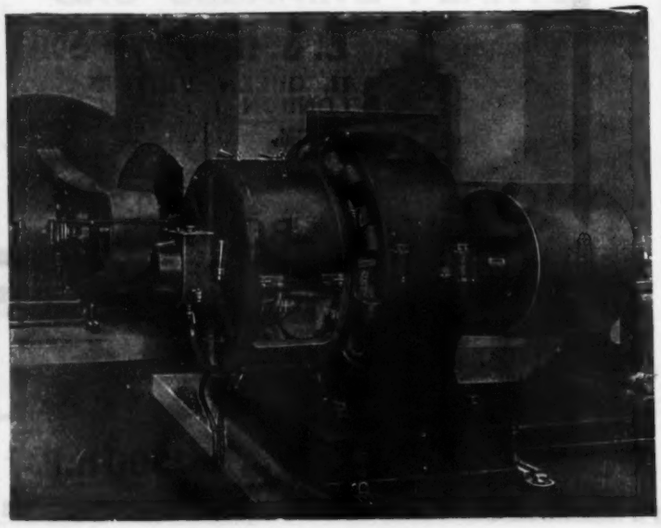

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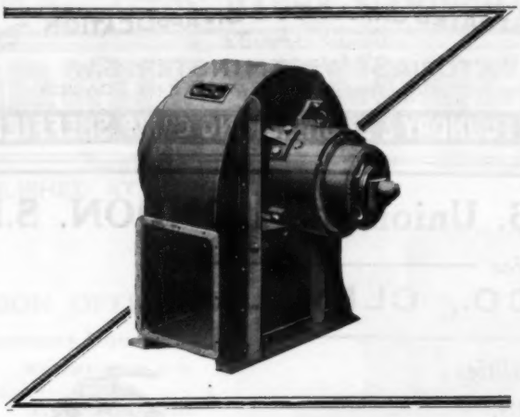

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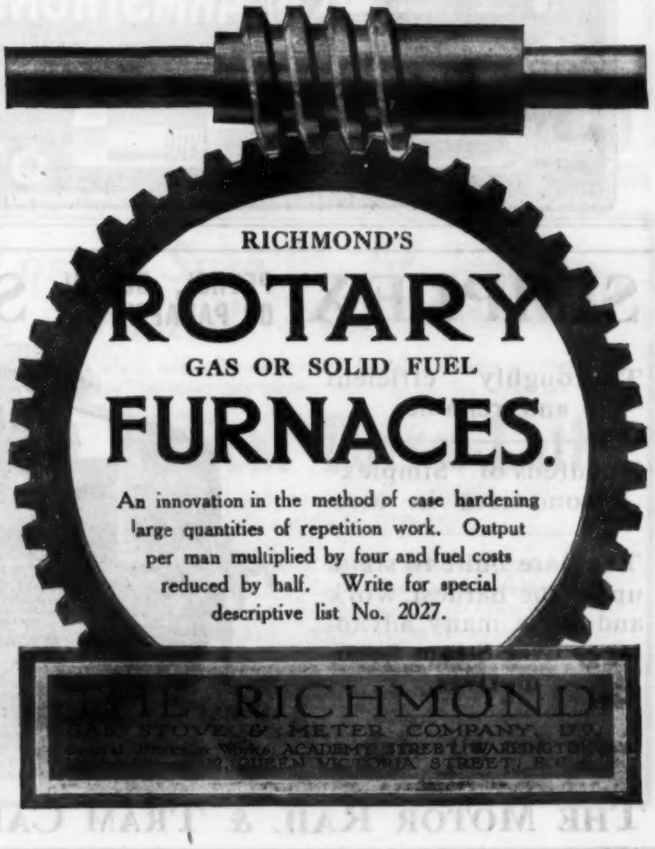
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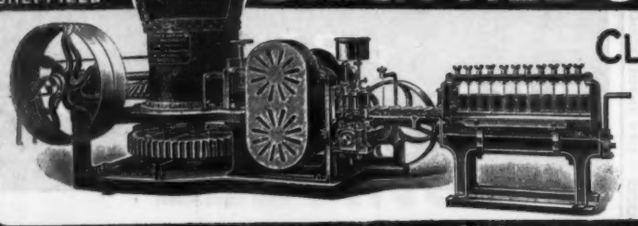

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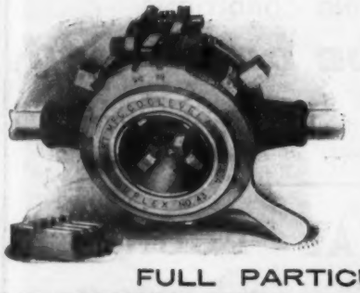

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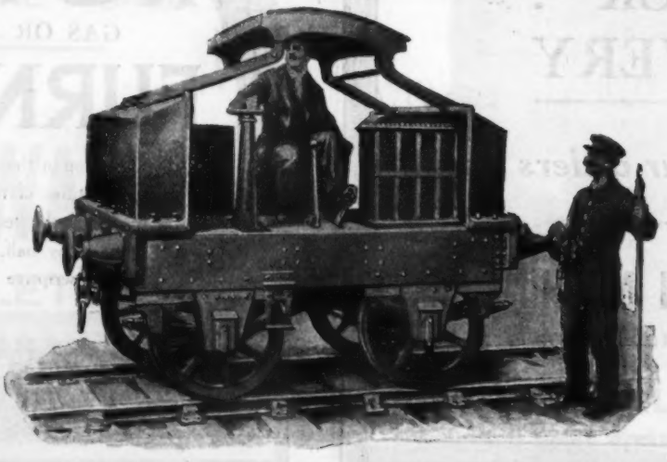

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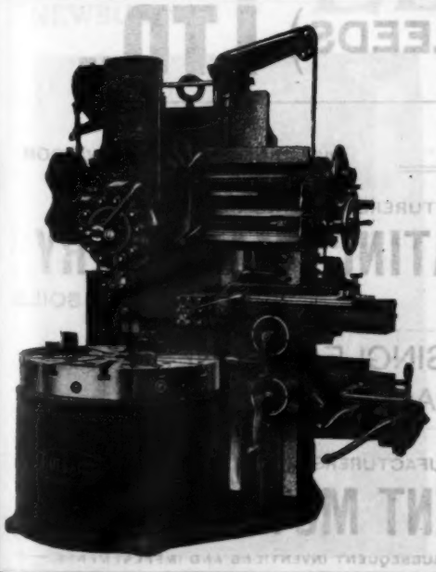

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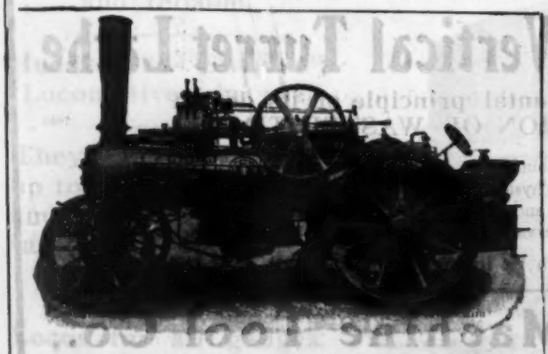

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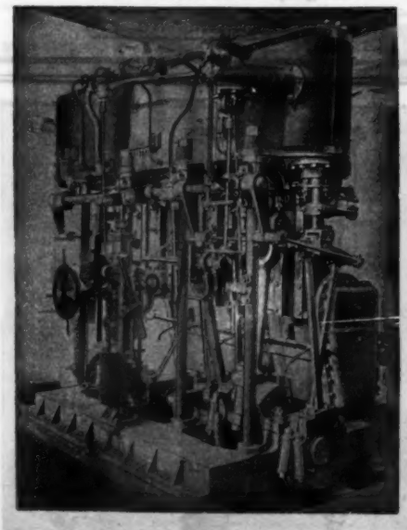

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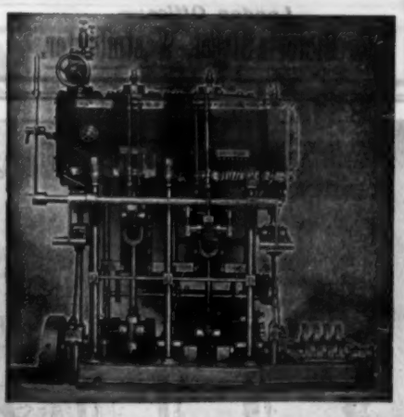

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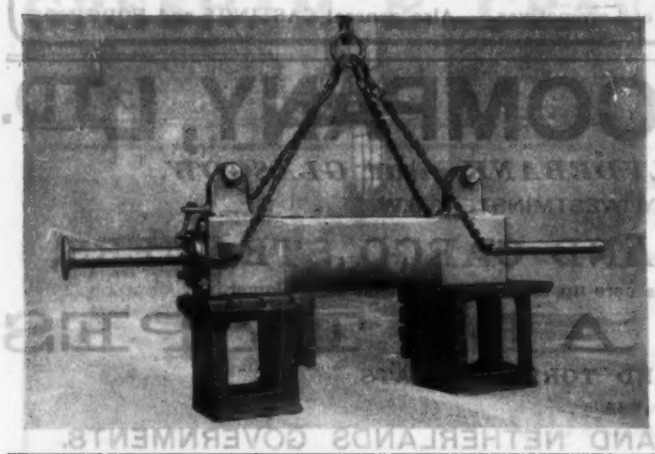

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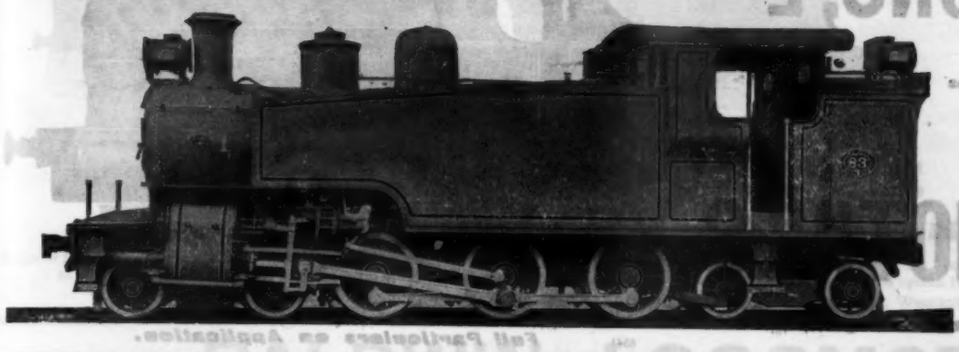

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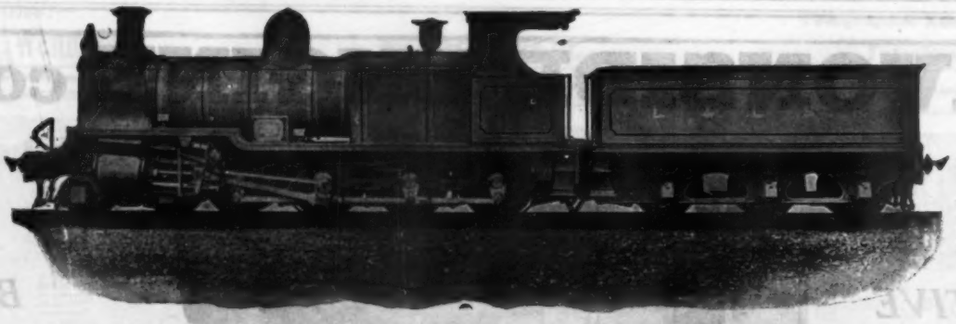

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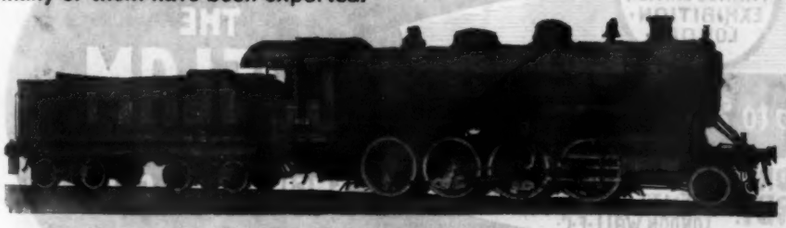

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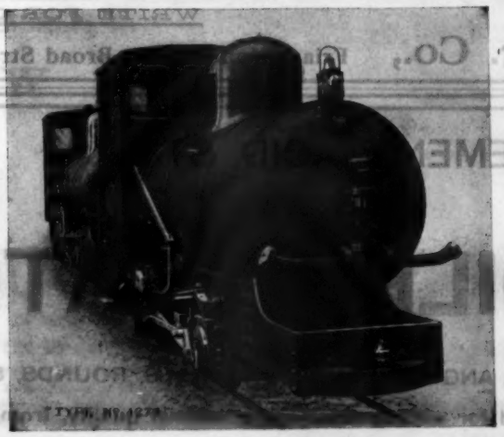

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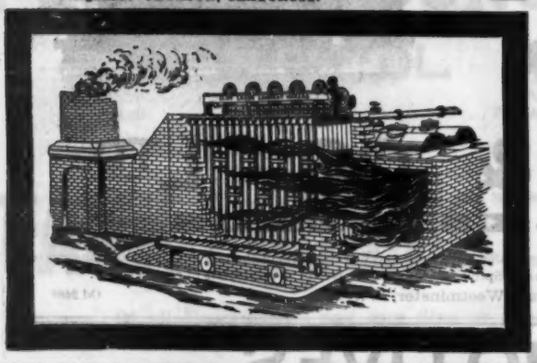

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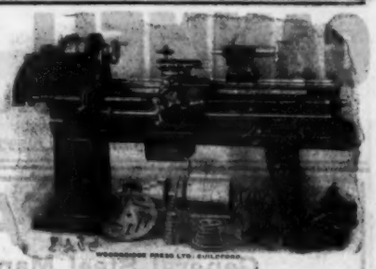

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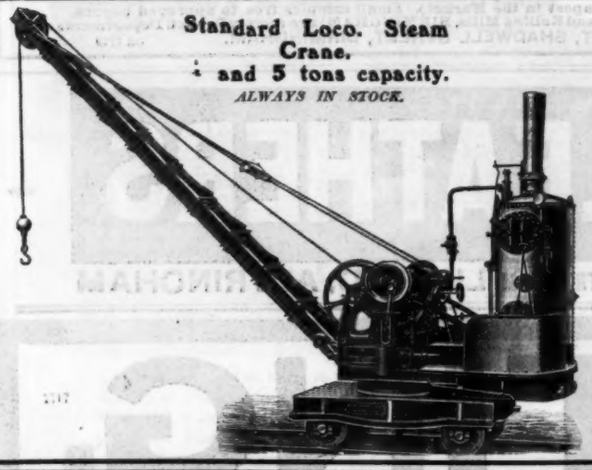

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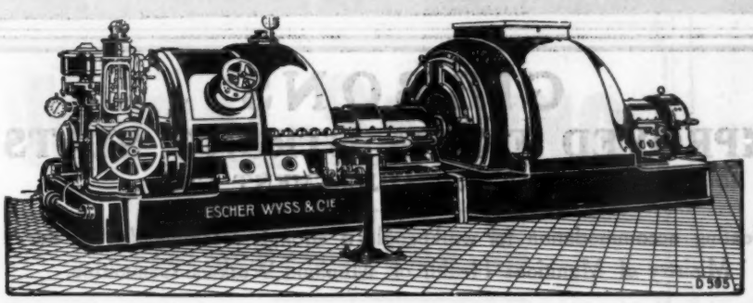

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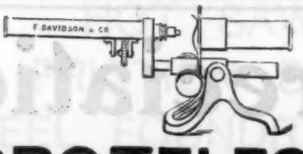

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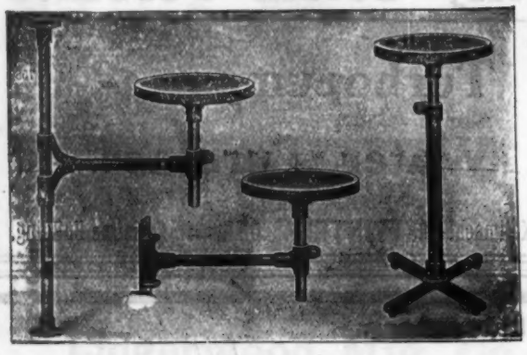

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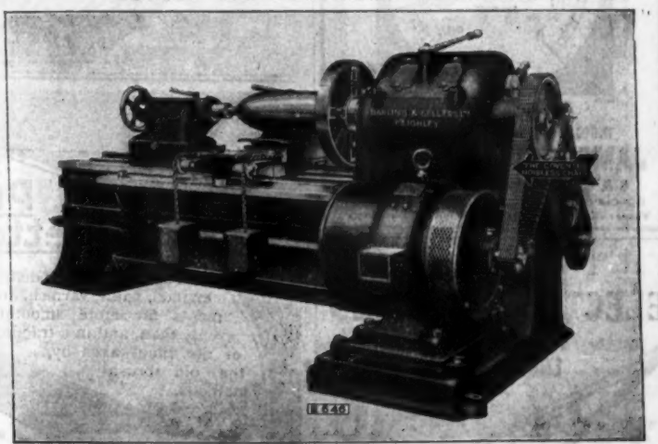

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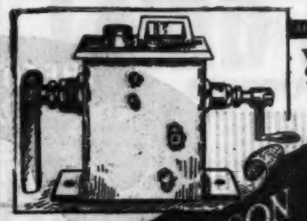
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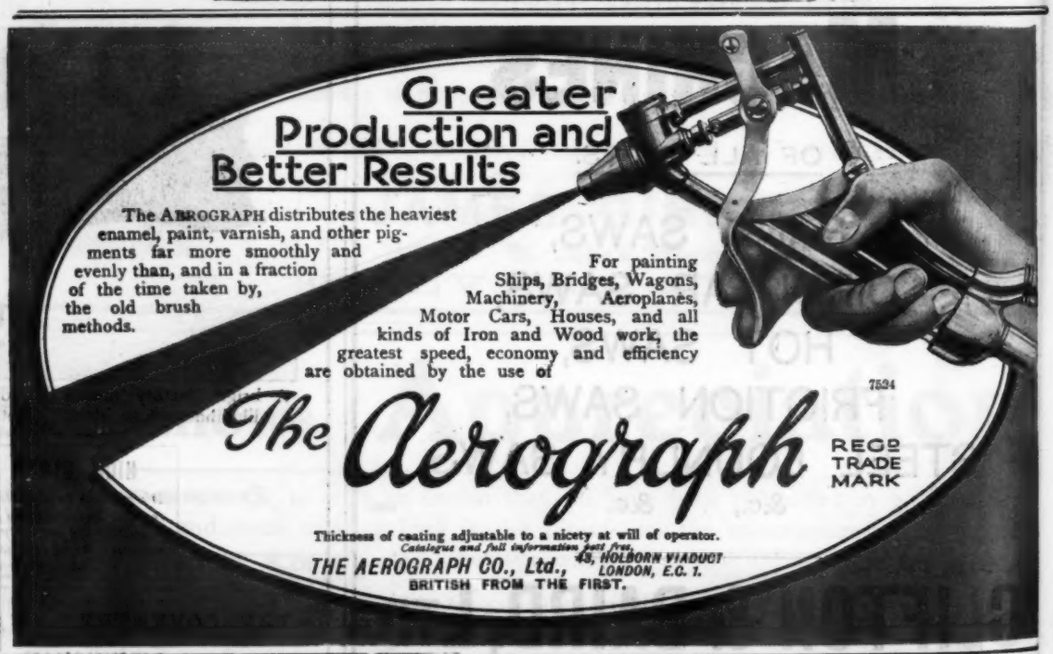
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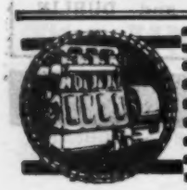
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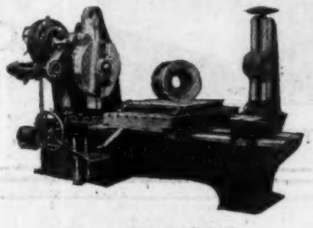

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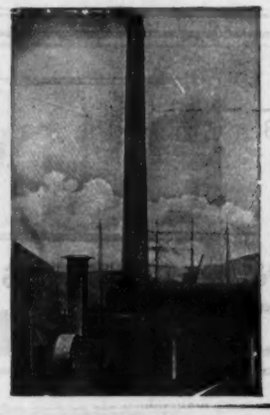

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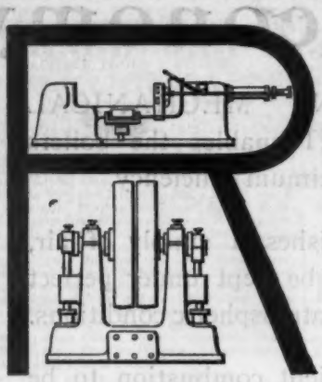

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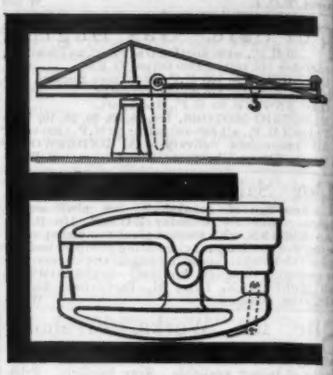

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Education Office, JOHN A. HARTLEY,
St. Helens. Secretary for Education.
20th June, 1919. W 726

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W 737

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Works Manager, for Railway Carriage and Wagon Works. 1000 to 1250 hands. Steel and timber wagons. Must be conversant with modern works methods and quantity production, tactful, good organiser, energetic and progressive. State qualifications, experience and salary expected. Copies only of testimonials, in strictest confidence.—Address, W 843, Offices of ENGINEERING.

Assistant Engineer Required immediately for Contract Department of Engineering firm in Midlands. Steam Turbine and Electrical Plant experience essential. State qualifications, age and salary expected.—Address, W 438, Offices of ENGINEERING.

Wanted, Young Engineers for the East by a Colonial Firm of Contractors, who could quickly qualify for positions as Managers after experience of local conditions. Qualifications desired—good training in drawing office and ability to supervise work in shops and superintend its erection on the site; training in some branch of engineering, mechanical, structural or reinforced concrete construction; business acumen and capacity to conduct preliminary commercial negotiations and to carry through successfully to the end. Unmarried. Salary £6.0-£750 on three years' agreements. State age, experience and qualifications. — Write, BOX F 354, LEE AND NIGHTINGALE, Advert. Offices, Liverpool. W 834

Required for the Service of the GOVERNMENT of INDIA, an ASSISTANT FOREMAN (electrical engineer) in the Harness and Saddlery, Factory, Cawnpore.
Candidates must be physically fit for service in India. They should have had experience in a central power station with continuous current dynamos directly coupled to engines driven from Lancashire or other boilers, and be capable of taking charge of such a station, and should have a knowledge of mains and motors. Also they should have had a good mechanical training. The selected candidate will be required to obtain in India a first-class boiler certificate to enable him to hold charge of boilers and engines under the Boiler Act.
TERMS.—Engagement for five years with option of extension if approved by Government. SALARY, Rupees 280 per mensem, rising annually by Rs. 10 to Rs. 350 per mensem. Rs. 350 per mensem for the sixth and subsequent years if retained. War bonus 30% of salary. Free quarters, medical attendance and second-class passage out and home.—Further particulars and Forms of Application from the DIRECTOR GENERAL OF STORES, India Office, Whitehall, S.W. 1.
Last date for receipt of applications, 7th July.
W 819

Reinforced Concrete Engineer experienced specialist designer with good technical education, for head office of leading firm; capable of supervising a number of junior designers. State qualifications, experience, age; good opportunity for the right man.—Address, CHIEF ENGINEER, Trussed Concrete Steel Co., Ltd., 23, Cranley Gardens, South Kensington, S.W. 7. W 536

Mechanical Engineer for the East, single, experience with gas and oil engines essential, electrical experience a recommendation.—Reply, stating age and with copies of testimonials and statement of experience, to Messrs. BROWN & CO., LTD. (Ceylon), 370, Mansion House Chambers, London, E.C. 4. W 531

Wanted, thoroughly capable ENGINEER, for large oil mill in Egypt; must have experience of crushing cottonseed and have sufficient electrical knowledge to maintain generator and motors and supervise minor repairs; permanent position.—Address, W 549, Offices of ENGINEERING.

Engineer, about 27, of Good appearance, to travel London for speciality machines.—Address, giving full particulars and salary required, W 675, Offices of ENGINEERING.

Sales Engineer Wanted, for works sales department of an electrical manufacturing firm. Must have had experience in estimating and drafting tenders. Real live man wanted, of proved ability and progressive ideas.—Address, stating experience and salary, W 709, Offices of ENGINEERING.

Works Organizer and Output ENGINEER.—An important firm, having several works, REQUIRES the SERVICES of a thoroughly competent ENGINEER (preferably with knowledge of brass foundries and finishing shops), to act as overhead organizer of and to give supervision and advice to works managements. Only a first-class man thoroughly up-to-date in best methods of modern shop practice and with good organizing ability need apply.—Address, W 750, Offices of ENGINEERING.

Engineering Firm Require bright young ENGINEER as progress traveller to urge and press delivery of machines and equipment on order. Commencing salary £350-£400 per annum. Good prospects for go-ahead man.—Write "A.A.," care of STREETS, 30, Cornhill, E.C. 3. U 632

Wanted, a Competent Selling REPRESENTATIVE for a Midland district by a leading firm of Lift and Hoist engineers.—Address, in first instance, stating age, experience, and salary required, W 654, Offices of ENGINEERING.

Chemist to take Charge of laboratory of brass and copper tube works; position of great scope for man of proved ability. State extent of knowledge of works practices. Age, salary (present or required).—THE YORKSHIRE COPPER WORKS, LTD., Leeds. W 411

Assistant Estimator Wanted, by a firm in the Midlands used to preparing tenders, specifications, etc. Knowledge of gas and oil engines essential.—State experience, age and salary required, W 543, Offices of ENGINEERING.

Wanted Immediately, Capable CLERK to take charge of department, comprising ordering of materials, stores and despatch. Must be good organizer, and with engineering experience preferred.—Address, stating age, experience, salary, and when free, W 782, Offices of ENGINEERING.

Foreman Required by old- established firm in London, engaged in the manufacture of Tanks and Light Structural steel work. Must be thoroughly experienced in all kinds of Plate work, able to supervise the making of templates, and also possess good organising ability and knowledge of handling men with a view to expediting output.—Write, stating age, salary required and qualifications to "K.C.," c/o STREETS, 30, Cornhill, London, E.C. 3. W 605

Wanted, Good Foreman for small engineering works, about 35 years of age. Must be good organiser, with good experience in hydraulic and general engineering work. State all particulars as to exact work previously engaged upon. — Address, A 51, BUCHANAN'S Advertising Offices, 17, James Street, Liverpool. W 700

Wanted, by Firm Starting the Manufacture of Pneumatic Hammer Drills, WORKING FOREMAN, to take charge. Must have experience in Heat Treatment of Steel. Excellent prospects for the right man.—Address, W 720, Offices of ENGINEERING.

Required, for the Service of the Government of India, an ASSISTANT FOREMAN, for the Gun and Shell Factory, Ishapore.
Candidates must be physically fit for service in India and should be between 25 and 30 years of age. They should be thoroughly good practical iron and brass moulders, and should have served a regular apprenticeship in the moulding trades; should have had experience in foundry cupola practice and mixing of pig iron for any nature of casting, including chill rolls; and should be able to mix and cast non-ferrous alloys. A knowledge of steel moulding is desirable but not essential.
TERMS.—Engagement for five years and option of extension if approved by Government. SALARY.—Rs. 280 per mensem, rising annually by Rs. 10 to Rs. 300 per mensem. Rs. 350 per mensem for the sixth and subsequent years if retained. War bonus 20 per cent. of salary. Free quarters, medical attendance and second class passage out and home.
Further particulars and Forms of Application from the DIRECTOR-GENERAL OF STORES, India Office, Whitehall, S.W. 1. W 766
Latest date for receipt of application 7th July.

Press Shop Production Fore- MAN.—WANTED, Live MAN, with experience of large, rapid production on medium drawing-through presses; experience on cartridge work an advantage.—Write, stating full particulars, qualifications, age, and wages required, PRESS, care of CROSSLEY & Co., Ltd., 57, Coleman Street, E.C. W 780

Capstan and Auto Foreman REQUIRED for small department in large works engaged on accurate work, Ward's Capstans 6¼ in. and Acme Autos; must be live man with experience.—Write, stating full particulars, qualifications, age, and wages required, CAPSTAN, care of CROSSLEY & Co., Ltd., 57, Coleman Street, E.C. W 847

Sample Passer or Melting Shop FOREMAN REQUIRED, with experience in hot and cold metal open hearth basic steel furnaces, for the North-East coast.—Address, stating age, experience and salary required, W 444, Offices of ENGINEERING.

Foreman Wanted by Engi- neering concern in Manchester district, to take charge of fitting department on electrical machinery (motors, generators, etc.). Only those who have already held positions as Foremen need apply. Good opening for energetic man. Applications (which will be treated in confidence) should state age, experience, and salary required.—Address, W 802, Offices of ENGINEERING.

ROYAL SIAMESE STATE RAILWAYS.

Applications are Invited for the POSITION of Electrical FOREMAN to the above Railways.
Candidates should have good all-round electrical training; be capable of taking charge of the complete electrical equipment of Railway Workshops, using Direct Current, and preferably be familiar with the care and maintenance of Stone's Electric Train Lighting System, though the latter is not essential.
The engagement will be for three years in the first instance, at 350 Ticals per month for the first year; 375 Ticals per month, second year; and 400 Ticals per month, third year.
13 Ticals = £1, approximately.
Apply by letter, stating age, married or single, and when at liberty; and giving full particulars of education, training, and experience, to:—
Messrs. C. P. SANDBERG,
70, Victoria Street, S.W. 1.
W 808

Good Draughtsman WANTED,
well acquainted with Motor Car Engine and Aeroplane Engine Work. Good salary and working conditions.
Applications, giving full particulars of experience and salary required, together with copies of any testimonials, to be addressed to:—
THE ASSISTANT SECRETARY,
PETER HOOKER, LTD.
(The Gnome & Le Rhone Engine Co.),
Blackhorse Lane,
Walthamstow, E. 17.
W 283

Chief Draughtsman for Con- structional Engineering Works in Wolverhampton District, with some experience in designing tools for Hydraulic Plate Press Work; also of the Construction of Sheet-Metal Working Machinery. State age, experience and salary required.—Address, W 261, Offices of ENGINEERING.

Draughtsman Wanted for General Engineering Works (South Wales district), preferably accustomed to making detail drawings of factory plant and colliery machinery; must be able to get out weights and quantities for estimates quickly and accurately.—Address, stating age, experience and salary required, W 564, Offices of ENGINEERING.

Engineers and Draughtsmen with previous practical experience of the design of ferro-concrete structures REQUIRED by L. G. MOUCHEL & PARTNERS, Ltd., of 38, Victoria Street, S.W., in their drawing office. Applications should in the first instance be made by letter stating age, experience and salary required. W 565

Wanted, Leading Draughts- MAN, to take charge of small ship drawing office, engaged upon wood launches and boats, flying-boat hulls, aeroplane floats, etc. Must be able to undertake usual ship calculations, and work out stresses.—Address, stating experience, salary expected, W 766, Offices of ENGINEERING.

Well-established Firm REQUIRES DRAUGHTSMAN, for hand and electric cranes, Birmingham district.—Address, stating age, wages, and experience, W 768, Offices of ENGINEERING.

Draughtsman for General and Mechanical Engineering, preferably with practical and technical training. Experience of plant lay-out an advantage.—Address, stating age, experience, and salary required, and when at liberty, W 757, Offices of ENGINEERING.

Draughtsman Required for constructional engineering works in Midlands, thoroughly capable in general constructional steel work. Experience in gas works plant a recommendation, though not essential. State age, salary and full particulars.—Address, W 837, Offices of ENGINEERING.

Draughtsmen Required (Senior and Junior) for Structural Steelwork, in London district. Roof girders and stanchions for steel-framed buildings, &c. Must be practical and theoretical men. State age, salary, experience, &c. —Address, W 838, Offices of ENGINEERING.

Appointments Open continued on page 158.

Assistant Mechanical Engineers REQUIRED, for Cement Company in Hong-Kong, age 28-30, single, well-educated. Applicants must have practical and technical training and mill work experience. Three years' agreement.—Apply, BOX 976, LEATHWAIT & SIMMONS, 5, Birchin Lane, E.C. 3. W 795

Wanted, a Works Man, with all-round experience capable of producing in quantity small marine engines of the two cycle type, reversing gears, and marine equipments. Applicants must have had good machine shop experience and must have had experience in erecting and testing internal combustion engines; must also be familiar with modern workshop routine, costing, price setting, etc. Applicants must be workers, not afraid of soiling their hands, good disciplinarians, methodical, good timekeepers and out to study their employers' interests. Good salary to the right man, with a liberal bonus on output.—Address, stating in full, education, experience, age and salary required, W 727, Offices of ENGINEERING.

Wanted First-class Foundry MANAGER, to be a good organizer for repetition and sectional work. Good salary offered. —Address, W 777, Offices of ENGINEERING.

Engineers.—Wanted for large concern in the East, several JUNIORS with good general mechanical shops and drawing office training; age 23 to 28, single.—Address, giving full particulars as to training and experience, "Z. P." 800, care of Messrs. DEACON'S, Leadenhall Street, London, E.C. 3. W 813

Surveyor Engineers.—Wanted for the East, Two JUNIORS; must have good general training; age 23 to 28, single.—Address, giving full particulars as to training and experience, "Z. O." 799, care of Messrs. DEACON'S, Leadenhall Street, London, E.C. 3. W 814

Wanted, Experienced REPRESENTATIVE for London office of Engineers, making turbines, engines and boilers.—Address, stating experience, age and salary required, W 797, Offices of ENGINEERING.

Wanted at Once by Well- known Engineering Firm LEADING DRAUGHTSMAN experienced in the design of large high speed heavy oil engines of the vertical type. Man with knowledge of latest aero engine practice preferred. Give full particulars and salary.—Address, W 770, Offices of ENGINEERING.

Wanted by Large Engineering Firm SENIOR and JUNIOR DRAUGHTSMEN experienced in oil engine design, preferably of the vertical two-cycle type. State age, wage, and experience.—Address, W 771, Offices of ENGINEERING.

Wanted, by Midland Engineering Firm, ESTIMATING ASSISTANT, with good drawing office experience, accustomed to calculating weights and quantities; must be quick, neat, accurate and energetic; state age, experience, salary.—Address, W 778, Offices of ENGINEERING.

Wanted for Eastern Counties experienced DRAUGHTSMAN to take charge of design of large two-cycle vertical oil engines. Marine experience an advantage. State age, experience and salary required.—Address, W 742, Offices of ENGINEERING.

Draughtsman Wanted; Experience in motor car or aero engine design essential. Give full particulars of age, experience, and salary required.—Address, W 748, Offices of ENGINEERING.

ROYAL SIAMESE STATE RAILWAYS.

Applications are Invited for the POSITION of Chief DRAUGHTSMAN to the above Railways.

Candidates should have had good general and technical education, have served their time as Mechanical Engineers, and had subsequent experience in the design and construction of Railway Carriages and Wagons. Knowledge of Locomotive design and General Engineering is also necessary.

The engagement will be for three years in the first instance, at a salary of 300 Ticals per month for the first year; 320 Ticals per month for second year; and 340 Ticals per month for third year, with usual field allowances. 13 Ticals = £1 approximately.

Apply by letter, stating age, married or single, and when at liberty, and giving full particulars of education, training and experience to:—

Messrs. C. P. SANDBERG,
70, Victoria Street, S.W. 1.
W 809

Wanted, by Firm of consulting engineers, naval architects and marine surveyors in London, DRAUGHTSMAN accustomed to ships' designs, specifications and calculations with practical knowledge wood and steel shipbuilding.—Address, by letter, stating age, experience, salary required to N. A. 330, care DEACONS, Leadenhall Street, E.C. W 811

Storekeeper, Wanted for Large Concern in the East, TWO JUNIORS. Must have considerable experience in engineering materials. Age 22 to 28, Single.—Address, giving full particulars as to experience, "Z. R. 801," c/o Messrs. DEACON'S, Leadenhall Street, London, E.C. 3. W 812

Wanted, Draughtsman, Manchester district, must have experience in detailing Conveying and Elevating Machinery. State experience, age and salary required.—Address, W 830, Offices of ENGINEERING.

Draughtsman Required by firm of Engineers in the Peterborough district; must have had experience in lampless high compression semi-Diesel engines.—Address, full particulars of experience, and also salary required, to W 839, Offices of ENGINEERING.

Draughtsmen Wanted, One with Dredge experience; one with experience of Pontoon or Structural Steelwork; and one having a good knowledge of Cranework, for London office.—Address, stating experience, age, and salary required, W 517, Offices of ENGINEERING.

Wanted, Two Experienced DRAUGHTSMEN for large iron and steel works in the Midlands; previous experience of steel works and blast furnace plant absolutely necessary. —Address, W 287, Offices of ENGINEERING.

Leading Draughtsman REQUIRED, experienced in modern Steel Plant, Rolling Mills, Furnaces, &c. State age, experience, and salary required.—Address, W 628, Offices of ENGINEERING.

Wanted, Two Good, Reliable MECHANICAL DRAUGHTSMEN, preferably with experience in Steam Power Plant and Boiler House Equipment. Permanency.—Apply, stating age, experience, and wages required, J. HOPKINSON & CO., Ltd., Britannia Works, Huddersfield. W 549

Draughtsman, First-class Man, experienced in designing lay-out arrangements of Mechanical Handling and Conveying Plants, REQUIRED for London office of manufacturing Engineers. W 815

Experienced Crane Draughtsman (Steam and Electric) WANTED. Good salary to suitable man.—Address, stating age, experience and salary, W 546, Offices of ENGINEERING.

Wanted, up to Half a Dozen DRAUGHTSMEN, used to the designing of repetition work. State age and salary required. —Address, W 679, Offices of ENGINEERING.

Draughtsmen, with Experience of the design of Turbines or Condenser Plants, WANTED by large Engineering concern in North-West district. Capable men only required, for whom permanent positions can be assured.—Address, with particulars of age, experience, and salary required, to W 672, Offices of ENGINEERING.

Motor Vehicle Draughtsman (pleasure car or lorry), WANTED immediately. —Address, stating full particulars, W 686, Offices of ENGINEERING.

Wanted, by Large Firm of Commercial Motor Vehicle Manufacturers, Senior and Junior Jig and Tool DRAUGHTSMEN. —Address, stating full particulars of training and experience, age, and salary required to CLAYTON & CO., Ltd., Karrier Works, Huddersfield. W 570

Capable Draughtsman Wanted in Yorkshire, experienced in all kinds of hydraulic Machinery and Cranes. State age, experience, and salary expected. — Address, W 704, Offices of ENGINEERING.

Structural Engineering.—Good OPENING for First-class DRAUGHTSMAN. Progressive firm; Manchester district.—Address, stating age, salary, and full details of experience, W 714, Offices of ENGINEERING.

Draughtsman Required, Ex- perienced in Aero Engines or Motor car work.—Write, stating age and salary required, W 717, Offices of ENGINEERING.

Draughtsman, with Ex- perience of cable and winding machinery, for designing and lay-out of plant. Good position for really capable man.—Address, stating age and references, and when at liberty, W 718, Offices of ENGINEERING.

Draughtsman Wanted, for boiler and superheater work, good prospects. —Address, giving full particulars of experience, W 810, Offices of ENGINEERING.

Draughtsman Required for Engine Works.—Applicants to state age and give a short record of experience, also wages required, to the CALEDON SHIPBUILDING AND ENGINEERING CO., LTD., Dundee. Envelope to be marked "Application for Draughtsmanship." W 736

Structural Draughtsmen REQUIRED, able to take out quantities, also accustomed to the preparation of estimates; good opportunities for suitable men.—Address, stating age, experience and salary required, W 731, Offices of ENGINEERING.

Two Draughtsmen Required, one senior, one junior; London area. Previous experience in making workshop details for constructional steelwork essential.—Address, stating age, previous experience, and salary required, W 772, Offices of ENGINEERING.

Draughtsman Wanted by firm of Engineers in Midlands. One with Rolling Mill experience preferred. — Write, stating age, experience and salary required, to W. H. A. ROBERTSON & CO., LTD., Lynton Works, Bedford. W 790

Young Draughtsman Re- QUIRED, general engineering in London, gas plant knowledge an advantage but not essential. State age, experience, salary, and if disengaged.—Address, W 71, Offices of ENGINEERING.

Draughtsman, Experienced WANTED with knowledge of Gas Plant and Structural Work. Able to prepare estimates preferred.—Apply, with full particulars and stating salary required to W 807, Offices of ENGINEERING.

Draughtsman.—First-class Machine Tool Man WANTED. Must be up-to-date live man with experience in checking. Excellent prospects for man out to work.—Address, full particulars, age, experience, and salary required W 747, Offices of ENGINEERING.

A First-class Draughtsman, thoroughly conversant with general Chemical Works practice. Must have a good theoretical and shop training. Permanency for a good man.—Address, W 745, Offices of ENGINEERING.

Draughtsman Required, for Jig and Tool Work, in large Midland Engineering factory. Must have had experience on this class of work.—Address, stating age, experience, and salary required, W 746, Offices of ENGINEERING.

Draughtsman Wanted Im- mediately. Elevator and conveyor experience essential.—Address, stating age, experience, and salary required, W 839, Offices of ENGINEERING.

Reinforced Concrete Work.— DRAUGHTSMEN REQUIRED for engineer's office in Manchester. Must be thoroughly experienced and able to make completed working drawings for colliery and steel works plant. State full particulars of experience and salary required.—Address, W 743, Offices of ENGINEERING.

LIVERPOOL CORPORATION WATERWORKS.

The Water Committee of the Liverpool Corporation

Require the Services of a Temporary CIVIL ENGINEERING DRAUGHTSMAN with experience in waterworks design and the preparation of Parliamentary plans.

The appointment will be of a temporary character, at a Salary of £200 per annum, with war bonus, which at present is 30s. per week.

Ex-Service man preferred.

Applications, with particulars of training and experience, to be sent to the WATER ENGINEER, 55, Dale Street, Liverpool, not later than Friday, 4th July, endorsed "Civil Engineering Draughtsman." W 749

Draughtsman, Experienced junior, for jig and tool drafting REQUIRED at once by firm near London manufacturing motor cars. Write stating age and salary required to Chief Jig and Tool Draughtsman.—Address, W 836, Offices of ENGINEERING.

Wanted, Experienced Struc- tural DRAUGHTSMAN for Westminster office.—Address, giving age, experience, salary required, and when at liberty, W 831, Offices of ENGINEERING.

SITUATIONS WANTED.

Appointment Required by demobilised R.E. officer, experienced and a good worker.—Address, W 701, Offices of ENGINEERING.

Works Manager, age 39, will shortly be OPEN for ENGAGEMENT. 24 years General and Repetition Engineering experience with large firms in foundry, smithy, machine, and fitting shops production. Thorough knowledge of modern machinery. Capable organiser and controller of labour.—Address, W 683, Offices of ENGINEERING.

Works Manager (40), Desires POSITION. Experience as Manager of General Engineering business, including Drawing Office, pattern shop, foundry machine shop, smithy, and boiler shop. Used to correspondence, interviews, travelling, and all office routine. Specialised in repetition work during war.—Write No. K 106, KEITH AND CO., Advertising Agents, Edinburgh. W 781

Assistant Manager, A.M.I. Mech.Eng., 1st class B. of T., DESIRES similar POSITION with a firm engaged on Marine Engineering or Marine Auxiliaries. Seven years' marine engineering experience. Age 35.—Address, W 800, Offices of ENGINEERING.

Foreman Blacksmith (33), SEEKS POST, well-up in Die-Sinking and Drop-Stamping for Carriage, Wagon, Loco., general engineering, etc. Good organiser, disciplinarian, tactful and energetic. State Salary.— Address, REID, 81, High Holborn, W.C. 1. W 721

Demobilised Officer, 4½ years' service, A.M.I.M.E. and A.G.C.I., age 35, single, REQUIRES POSITION of Trust at HOME or ABROAD. Extensive general experience Electrical and Mechanical, including installation and maintenance steam turbines and generators, petrol, paraffin and hot bulb type engines, marine and other types.— Address, W 735, Offices of ENGINEERING.

Electrical and Mechanical Engineer, B.E. (38), DESIRES responsible POSITION, home or abroad, 18 years' pre-war experience. Works, Central Station, Factory, etc. Good testimonials and character; references.— Address, W 640, Offices of ENGINEERING.

Structural Engineer, A.M.Inst. C.E., experienced, both practically and theoretically, in heavy steel bridgework, and all kinds of structural steelwork, also Ferro-Concrete work, DESIRES an APPOINTMENT of responsibility. Highest credentials. — Address, W 794, Offices of ENGINEERING.

Engineer, A.M.I.C.E., at present in charge of export department, DESIRES CHANGE, preferably in London.— Address, W 648, Offices of ENGINEERING.

Demob. Officer, A.M.I.C.E., A.M.I.Mech.E., DESIRES APPOINTMENT; experience hydraulic machinery and dock works; nearly three years' active service.—Address, W 657, Offices of ENGINEERING.

Mr. Charles G. Watson, late District Engineer, Callenders Cable and Construction Co., Ltd., Newcastle-on-Tyne (now demobilised), is PREPARED to TAKE UP an APPOINTMENT as Constructional Manager or Engineer; extensive experience of large power transmission work on N.E. coast.—2, Wimborne Road, N. 17. W 671

Engineer Officer, Royal Navy, about to be demobilised, with 20 years' experience. Marine, general and commercial experience, SEEKS responsible POSITION with engineering firm. Has held position as manager and has some connection amongst shipowners and elsewhere. If necessary is willing to invest a substantial sum as a guarantee, or would consider partnership with small firm desiring to extend its business.—Address, W 514, Offices of ENGINEERING.

Engineering Draughtsman, age 34, with wide experience, six years shop and 12 years drawing office, structural, mechanical and electrical, DESIRES POSITION as Progress Traveller or responsible out-door work, Scotland preferred.
Address, W 641, Offices of ENGINEERING.

Engineer (31) Seeks Appoint- MENT as engineer's assistant, or on technical staff; extensive knowledge of light internal combustion engines for all purposes, specially interested in marine work; well acquainted with modern methods, technical education.—Address, W 763, Offices of ENGINEERING.

Engineer, 35, Keen and able, with good record, SEEKS POSITION at home or abroad. Six years works Foreman for London Contractors. Knowledge of French and Spanish.—Address, W 723, Offices of ENGINEERING.

Works Manager Seeks an APPOINTMENT. Sound practical and technical experience with well-known firms; Foundry, Smithy, Fitting, and Machine Shop experience, and factory costs. Energetic disciplinarian, capable organiser and controller of all classes of labour.—Address, W 802, Offices of ENGINEERING.

Mechanical Engineer— (M.I.Mech.E.) with academic training and large technical and commercial experience gained in this country and on the Continent, late Russian representative of a large English manufacturing concern, fluent English, Russian and German, full knowledge of French, is OPEN for suitable ENGAGEMENT. Willing to go abroad. First class references.—Address, W 801, Offices of ENGINEERING.

Engineer (Water) Seeks POSITION. Demobilized Captain, R.E. Age 36. Expert in filtration, sterilization, chemical treatment, investigation, design, construction, operation. 20 years' office, laboratory, works and field. Wide experience all forms and and mechanical filtration, pumping, general waterworks engineering. Three years' Army on same work, home and abroad. —Address, W 840, Offices of ENGINEERING.

Engineer (32), expects to be demobilised this month. DESIRES APPOINTMENT as ASSISTANT WORKS MANAGER or ENGINEER to firm of Manufacturers. 13 years' general engineering experience before the war; 4½ years with the Royal Engineers during the war. Very energetic and good organiser.—Address, W 666, Offices of ENGINEERING.

Engineer, M.I.E.E., A.M.I.M.E., with sound commercial training, will shortly be demobilized, valuable experience gained during the war, SEEKS an APPOINTMENT as Representative in London of a well-established firm, manufacturers preferably of motor car and lorry accessories or some engineering speciality. Speaks French and Italian fluently. Good salary required, part of which advertiser is agreeable to being dependent upon results. Capital up to £500 could be invested in an approved concern with good prospects.
Address, W 621, Offices of ENGINEERING.

Mechanical Engineer, A.M.I.M.E. (32), public school, 15 years' sound practical and technical training, six years' shops, two years D.O., good posts held, steam, aero and car engines, steelwork construction, production engineer, control of men and women, good references, SEEKS POST; London preferred.— Address, W 668, Offices of ENGINEERING.

Electrical and Mechanical Engineer (30) with wide experience; technical practical and d.o., speciality jig and tools, plant and systematising for mass production, SEEKS POST as Asst. Manager or Asst. Works Engineer. —Address, W 786, Offices of ENGINEERING.

Hydraulic Engineer, with long and up-to-date experience in the design and construction of centrifugal, turbine and reciprocating pumps for all speeds and every service, DESIRES Responsible BERTH.—Address, W 796, Offices of ENGINEERING.

Junior Draughtsman, with seven years' shop experience, SEEKS Jig and Tool WORK; London district. Good technical education.—"ALPHA," 118, Heald Grove, Rusholme, Manchester. W 797

Maintenance or Erecting ENGINEER (35) DESIRES PERMANENCY. 13 years' factory experience, buildings, extensions, gas, steam and electric driving. Acid plant and phosphate mills a speciality.— ENGINEER, 48, Gateley Road, Brixton, London. W 776